GUIDE BOOK No. 10

EXCURSIONS

IN

NORTHERN BRITISH COLUMBIA YUKON TERRITORY AND NORTH PACIFIC COAST

GEOLOGICAL SURVEY
DEPARTMENT OF MINES
OTTAWA
1913

F. C. Dyer.

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IN

Northern British Columbia and Yukon Territory and along the North Pacific Coast

(EXCURSIONS C 8 AND C 9.)

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
Government Printing Bureau
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34883—1.

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CONTENTS.

34883—1½

Coast Range mountains, showing rounded glaciated character.

ERRATA.

GUIDE BOOK NO. 10.

PAGE.

3. In Contents, number "37" should be opposite "Yukon and Malaspina."
122. 5th line from top—for "Nunakak" read *Nunatak.*
124. 9th line in 3rd paragraph—for "Grillon" read *Crillon.*
125. 3rd line from bottom—for "John" read *Johns.*
126. Legend of photograph—for "on 1911" read *in 1911.*
127. 8th line from top—for "C. F. Wright" read *G. F. Wright.*
129. After first line in table—add *About 1814, Advance; Over 1 mile, W. Ogilvie.*
130. Substitute the following for the half of the table, below "Earthquake."

1899 to 1906.	Retreat....	30,360 ft....	4,337 ft. . .	F. E. & C. W. Wright
1906 to 1907.	Retreat....	1,320 ft....	1,320 ft. . .	Morse, Klotz.
1907 to Sept. 2, 1911.	Retreat....	13,200 ft. *a.*	3,300 feet. .	Tarr and Martin.
1911 to June. 1, 1912.	Retreat....	1,320 ft. *b.*.	8,745 ft . .	N. J. Ogilvie.
June 1 to Aug. 1, 1912.	Retreat....	7,425 ft....		

a. Estimated, and checked by photographs.
b. Accurately measured by Mr. Ogilvie as 14,520 feet of recession from 1907 to June 1, 1912.

PAGE.

137. 2nd line from top—for "47" read *76.*
139. Between "Present Day Glaciers" and "78"—add *65, 66, 72.*
143. Folded map of Hidden Glacier—for "Approximate Location of Front 1908" read *Approximate Location of Front 1905-6.*
143. 18th line from top—for "black glacier" read *Black glacier.*
146. 2nd line from top—following "The moraine terraces," add *evidently to be correlated with the deposits which form the fourth evidence.*
146. 8th line from top—after "evidently" add *the results.*
148. 3rd line in 2nd paragraph—for "72" read *26.*
148. 7th line in 2nd paragraph—for "26" read *74.*
153. 1st line at top—for "destroying " read *deflecting.*
156. In double starred note—for "on" read *in.*
156. 1st line in 3rd paragraph—for "Our" read *Other.*
158. Last line in table—add *Tributary of Anderson glacier; 80 miles northwest; 1912; D. W. Eaton.*
160. After 5th line in table—add *Muir; about 1814; over 1 mile; W. Ogilvie.*
160. 8th line from bottom—for "Before" read *Between.*
176. 7th line from top—For "Reed"read *Reid.*

34883

EXCURSION C 9.

PRINCE RUPERT AND SKEENA RIVER

BY

R. G. McConnell.

CONTENTS.

VANCOUVER TO PRINCE RUPERT.

The journey along the North Pacific Coast from Vancouver to Prince Rupert is made by ocean steamer. The distance is about 500 miles (804 km.), and the time occupied usually about 36 hours. The journey is continuous, no stops being made; and as much of the coast-line is passed in the night, only a brief general description is necessary.

Physical Features of the Coast.

The route from Vancouver northward along the Pacific Coast follows a long, partially submerged, island-filled depression, bordered continuously on the east by the Coast range and interruptedly on the west by the long mountain ridges of Vancouver and the Queen Charlotte islands.

The Coast range is a deeply dissected granitic ridge usually from 60 to 80 miles (96 to 128 km.) in width. It rises directly from the sea with few intervening flats or plateaus to height of 4,000 to 5,000 feet (1,219 to 1,524 m.), gradually increasing towards the axis of the range to 7,000 or 8,000 feet (2,133 to 2,438 m.) The mountains and mountain ridges are massively built elevations with steep, often craggy, slopes terminating in rounded, dome-shaped, and pyramidal summits. The heights as a rule are very uniform, although a few peaks rise to a considerable elevation above the general level. Deep, ice-worn, steep-sided valleys, often terminating in living glaciers, penetrate the range in all directions, and form one of its most characteristic features. The lower slopes of the mountains, where not too precipitous, are covered everywhere up to a height of 4,000 feet (1,210 m.) with a dense coniferous forest.

A fiord system is well developed all along the Pacific Coast from Vancouver northward. The fiords not only repeatedly penetrate the Coast range for distances which often exceed 100 miles (161 km.) in length, but similar deep, narrow, water-filled depressions, trending in different directions, separate the numerous islands fringing the coast both from each other and from the mainland.

The fiords are all very similar in character. They are steep-sided very regular troughs, usually from one to

two miles in width, sunk 500 to 1,500 feet (152 to 457 m.) below the present sea level. They are occasionally straight, but as a rule follow a winding course, sending off branches at intervals, and often opening out around rocky islands.

Two theories have been advanced to account for the origin of the fiords, one that they have been excavated below sea level by moving ice, the other that the coast has been depressed and that they are sea filled stream valleys smoothed, straightened and probably deepened to some extent by glacial action. The complexity of the system, the presence of midstream islands, and the northerly trend of a not inconsiderable number of the fiords are difficult to explain if the cutting was done entirely by ice.

Geology.

The Pacific Coast from Vancouver northward for several hundred miles is bordered continuously by a wide belt of granitoid batholithic rocks, the intrusion of which commenced and reached its maximum in upper Jurassic times, but continued also into Cretaceous times. These rocks vary little in general character along the coast for hundreds of miles. They are described in connection with excursions C1, C2 and C8. The ordinary variety outcropping everywhere along the coast is a coarse, greyish granodiorite, usually massive, but frequently distinctly gneissic. Dark basic and light colored acid varieties are not uncommon, but seldom cover large areas. The roof of the long line of batholiths has been largely removed by erosion, but inclusions of the rocks through which they were intruded, ranging in size from small fragments to areas several miles across, are seldom absent in sections across the granitic belt.

Between Vancouver and the northern end of Vancouver island, the western edge of the series of batholiths follows closely the mainland coast, and sedimentary and volcanic rocks, referred mostly to the Triassic, outcrop in the bordering islands. North of Vancouver island, the coast trends more to the north, and the groups of islands fringing it northward nearly to the mouth of the Skeena are all granitic in character. Opposite the mouth of the Skeena, a wide belt of altered sedimentary rocks, mostly quartz mica schists and crystalline limestones, border the

batholithic rocks on the west and are exposed in islands in Chatham sound and in a strip along the mainland.

Annotated Guide.

VANCOUVER TO PRINCE RUPERT.

Gulf of Georgia. This long irregular arm of the sea, separating the southern part of Vancouver island from the mainland, is followed north-westward from Vancouver to Valdez island, a distance of 150 miles (241 km.). The depression it occupies, usually from 12 to 20 miles (19 to 32 km.) in width, is attributed to crustal warping in Tertiary times along the western border of the Coast Range batholith. The depressed area is only partially submerged, the more elevated portions still rising above the surface as rocky islands.

Texada island, 50 miles (80 km.) northwest of Vancouver, the largest of these uncovered ridges, has a length of 30 miles (48 km.) and is built largely of massive porphyrites, probably of Triassic age, intrusive into a limestone referred on imperfect fossil evidence to the Carboniferous. The coal-bearing Cretaceous strata of Vancouver island formerly extended eastward across the gulf to Texada island, but have been largely removed by erosion, and are now only found in small isolated patches in sheltered basins along the west coast.

Texada island is well mineralized with deposits of the contact metamorphic type, situated usually near small dioritic or granitic stocks intruding the porphyrites and limestones. The ore bodies in the Marble Bay mine on the east coast, consisting mostly of bornite and chalcopyrite in a garnet-epidote-augite gangue, have proved very persistent, and the workings have now reached a depth of 1,170 feet (356 m.) below the land surface and 1,120 feet (341 m.) below sea level. An important range of magnetite lenses, some of large size, occur near the west coast along irregular granite-limestone and porphyrite-limestone contacts.

Glacial deposits made up of two boulder clays separated by a thick band of sands, silts and gravels, interglacial in age, form conspicuous banks in isolated areas on Texada, Savary, and other islands in the gulf, and also occur at intervals along both coasts. The beds in the

different areas are very similar in general character and sequence, and probably represent erosion remnants of a continuous, or nearly continuous sheet, which spread across the gulf and filled the depression it occupies to a height of about 300 feet (91 m.) above the present water level.

Valdez Island. The depression between the Coast range and Vancouver island is occupied north of the gulf of Georgia by the Valdez islands. They are separated from Vancouver island by a narrow strait, swept at the Seymour Narrows constriction by strong tidal currents.

The Valdez islands are situated along the contact between the batholithic rocks of the Coast range, and the bordering volcanics and sedimentaries, and like Texeda island are extensively mineralized.

Queen Charlotte Sound. North of the Valdez islands the channel between Vancouver island and the mainland gradually opens out into the Queen Charlotte sound, an irregular island-filled body of water extending northwestward to the head of Vancouver island. The numerous rocky islands in the sound are built mostly of massive and fragmental volcanics of Triassic age associated with argillites, quartzites and limestones. An outlier of coal-bearing Cretaceous strata occurs on the Vancouver island side opposite Malcolm island. Granitic batholithic rocks outcrop all along the mainland coast.

Fitzhugh Sound. North of Vancouver island, an open stretch of water exposed to the Pacific, about 25 miles (42 km.) in width, is crossed to Fitzhugh sound between Calvert island and the mainland. North of this point nearly to the mouth of the Skeena, a distance of 150 miles (241 km.), the ordinary steamship route follows a succession of narrow, often extremely picturesque, channels separating an almost continuous line of rocky, granitic islands from the mainland. The coast line is indented with numerous bays and deep fiords. Dean canal, one of these fiords, with its continuation, the valley of Salmon river, cuts completely across the Coast range.

Princess Royal Island. This is the largest island on the route north of Vancouver island. It is mountainous

throughout and is practically a portion of the Coast range, but is separated from it by a continuous deep channel. It is built mostly of greyish, gneissoid granites or granodiorites. Large gold bearing quartz veins occur in places near its west coast.

Grenville Channel. This channel separates Pitt island from the mainland. It is a typical fiord, and is remarkable for the straight course it follows. It has been excavated along a narrow band of schists, widening to the north, included in the batholithic rocks. Pitt island, like Princess Royal island, is monotonously rough and mountainous along its whole length of 50 miles (80 km.) Some of the triangular granite peaks reach elevations of 5,000 feet (1,524 m.)

Chatham Sound. From Grenville channel the southern part of Chatham sound is crossed to Prince Rupert, situated on Kaien island north of the mouth of the Skeena. A large inclusion or bay of sedimentary rocks lies in the batholith at this point, and exposures of schists and altered limestones occur in most of the low islands scattered along the sound.

GENERAL PHYSICAL FEATURES OF THE SKEENA RIVER DISTRICT.

The region traversed in the excursion from Prince Rupert to Telkwa, now made accessible by the construction of the Grand Trunk Pacific Railway, was practically unknown until recent years except to the furtrader, prospector and an occasional explorer, and even at present surveys are practically limited to the main waterways, and only the general geological features have been ascertained. The district includes the Coast range and a portion of the mountainous Interior region bordering it on the east, and bold relief is the dominant feature everywhere.

The Coast range, where crossed, has a width of about 60 miles (96 km) and, with the exception of some included schists, is everywhere carved out of coarse granitoid rocks. The mountains in the immediate vicinity of the Skeena valley are not high, seldom exceeding 5,000 feet (1524 m). They are as a rule densely forested below, and steep and

craggy above, but have been toned down by the moving ice of the Glacial period and rendered somewhat monotonous. Higher, partially snow-covered, and more impressive peaks are occasionally seen up tributary valleys. Small glaciers of the Alpine type occur at a few points, but do not descend to low levels.

The eastern boundary of the Coast range is not always easy to define, as it often merges insensibly into the high plateaus and mountains of the Interior. On the Skeena the main range is bordered on the east by a wide depression occupied north of the Skeena by the Kitsumgallum river. This great trench, 4 to 5 miles (6.4 to 8 km) wide in places, extends northward to the Nass and southward across the Coast range, reaching the sea at the head of Kitimat arm. It evidently represents an old, partially abandoned, valley of erosion possibly robbed by the Skeena.

East of the Kitsumgallum valley a second wide range of high nameless mountains, mostly built of schist and granite, is crossed. These connect to the south with the Coast range and may be considered a spur from it. After passing them the dry interior district is reached, and a change in the topography is immediately noted. The valleys of the Skeena and its tributaries become much wider, are frequently terraced, and the relief is expressed in long even ridges, or in isolated groups of high peaks mostly built of upturned Jurassic and Cretaceous strata surrounding granite cores. Among the prominent groups are the Rochers Déboulés at the confluence of the Skeena and Bulkley rivers, some peaks of which reach elevations of over 8,000 feet (2,438 m), and judging from their rugged angular character evidently exceeded the limits of glaciation, and the lofty Hudson Bay mountains bordering the Bulkley on the southwest.

The Skeena river, which is followed by the railway from its mouth eastward through the Coast range to its junction with the Bulkley, heads in some of its branches with the Fraser, and like it drains a large portion of the rough elevated country lying between the Coast range and the Rocky mountains. It is a wide, swift flowing stream, repeatedly dividing around low alluvial islands in its passage through the Coast range. In its upper reaches it becomes more confined and its course is interrupted by numerous short boulder-strewn rapids and by occasional canyons. It is ascended by river steamers to Hazelton at

the mouth of the Bulkley, a distance of 154 miles (247.8km), but its navigation, except near the mouth, is difficult and dangerous.

The valley of the Skeena, where it cuts the Coast range, is a deep, steep-sided trough, precisely similar to the fiord-like depressions filled with salt water so prevalent along the coast. It has however, been gradually silted up by the river down to about Mile post 40, and is bottomed with alluvial flats and islands. Above the mouth of the Kitsumgallum its character changes. The valley above this, at the end of the Glacial period was floored for some distance by estuarine, and farther up by glacial deposits, and in place of depositing its load the river is scouring out, and along most of its course is sunk in a secondary valley.

The secondary valley is mostly in drift, but along considerable stretches it cuts through these loose deposits down into the bed rock beneath, and contracts into a canyon. The rock walled portions are due, in part at least, to deviations of the stream from the lowest portions of its pre-glacial channel. Some of them may owe their origin to small post-glacial uplifts.

The Skeena valley, east of the semi-crystalline rocks which border the Coast Range batholith on that side, enters a more easily eroded region where it gradually expands in width, and the bordering slopes become much less regular.

The Bulkley river, which is followed after leaving the Skeena, is a wild unnavigable stream plunging over rapids or crowding through canyons along its whole course. The enclosing valley is very large, its width ranging from four (6.4 km.) to nearly ten miles (16 km.). It is bordered on the southwest, from the Skeena to Moricetown, by the high rugged Rochers Déboulés mountains, and from Moricetown to the Telkwa by the almost equally rough Hudson Bay mountains. On the northeast the bounding elevations are low and more even, seldom breaking into prominent peaks.

The valley is heavily drift covered, and a cross section usually shows a central terraced portion, bordered by uneven slopes, leading up to the bounding ridges and mountains. The river is sunk in a secondary, and for long reaches, rock-walled valley from Hazelton to Telkwa.

The grade of the Skeena from Essington, where the current practically ceases, to Hazelton, a distance of 154

miles (247.8 km.), averages 4.2 feet per mile (1.8 m. per km.), and that of the Bulkley from Hazelton to Telkwa, a distance of 58 miles (93.3 km.), 17.1 feet per mile (5.2 m. per km.). The elevation at Telkwa is 1,650 feet (502.8 m.) above sea level.

NATURAL RESOURCES.

The principal natural resources of the district consist, on the coast, of fisheries and the product of the forest, and in the interior of agriculture and mining.

The Skeena is a noted salmon river, and the fishing industry has been established on a firm basis for some years, and is still growing. The product of the numerous salmon canning establishments, located on islands off the mouth of the Skeena and along the mainland, is very large, in favourable seasons exceeding 200,000 cases. Other fishes of commercial importance are the cod, herring, oolachan, and farther away, near the Queen Charlotte islands, the halibut.

The Coast district is forested, practically everywhere, up to a height of about 4,000 feet (1,219 m.) above sea level. The principal forest trees along the lower part of the Skeena are the hemlock (*Tsuga Mertensiana*), the stately Sitka spruce (*Picea Sitchensis*), specimens of which frequently attain diameters of from 6 to 8 feet (1.8 to 2.4 m.), and the white fir (*Abies grandis*). The cottonwood (*Populus trichocarpa*) is well represented along the lower flats. Less common trees are the valuable yellow cedar (*Chamaecyparis nootkatensis*), and the red cedar (*Thuya gigantea*).

The area of land available for agriculture is very limited near the coast, but the country east of the Coast range, although generally rough and mountainous, contains a number of large areas suitable for this and kindred purposes. Among the most important of these are, the wide longitudinal depressions which follow the Kitsumgallum and Kitwancool rivers from the Skeena north to the Nass, the benches along the upper Skeena, and the great terraced valley of the Bulkley. Production as yet is small because settlement has barely commenced. It includes small fruits and apples in the valley of the Kitsumgallum, and roots and hardy cereals farther inland.

The mining industry is also only in its initial and experimental stages, but promises a rapid development. The mineral resources of the district include, bituminous coal in considerable areas in the valleys of the Telkwa and Bulkley rivers and other places, and lignitic coal on Driftwood creek. Numerous discoveries of metalliferous veins, some of large size, have also been made. These usually occur in the vicinity of intrusive masses which cut the rocks of the Hazelton formation, and are especially abundant in the mountains bordering the Bulkley on the east, south of Hazelton, and in the Hudson Bay, Babine, and Rochers Déboulés mountains. Silver-bearing galena and chalcopyrite are the principal valuable minerals present. The associated minerals include pyrite, arsenopyrite, zinc blende, stibnite, tennantite, and tetrahedrite.

Development work is in progress on a number of the properties, and on a few, considerable bodies of good ore have already been opened up.

GEOLOGY.

The formations traversed along the route of the excursion embrace the granitoid rocks and included schists of the Coast Range batholith, bordered on the west by altered sedimentaries, and on the east by a complex of partially altered volcanics. The latter are overlaid and succeeded eastward by a wide belt of middle Mesozoic, mostly tufaceous, rocks, intruded at numerous points by granite stocks.

A marked feature of the section is the preponderance along it of rocks of igneous origin, both intrusives and extrusives being widely represented.

The rocks have been subdivided into the following groups:—

SEDIMENTARIES AND VOLCANICS.

Lower Cretaceous	Skeena formation.
Jurassic, possibly including some Lower Cretaceous	Hazelton formation.
Triassic?	Kitsalas formation.
Upper Paleozoic?	Prince Rupert formation.

INTRUSIVES.

Jurassic to Lower Cretaceous....	Coast Range batholithic rocks.
Post-Lower Cretaceous.........	Granodiorite stocks, east of Coast range.

Skeena Formation. The rocks of this formation occupy isolated basins folded in with those of the Hazelton formation, and resting apparently conformably or nearly so on them. The exact relationship has not been worked out. The varieties commonly present are felspathic sandstones, conglomerates, hardened clays, shales usually more or less carbonaceous, and occasional seams of coal. The beds are less indurated than those of the underlying Hazelton formation, are seldom fractured, and usually undulate in open folds.

The shales are plant bearing in places. A small collection made by W. W. Leach and reported on by Dr. Penhallow contained the following species:—

Sequoia Rigida, Heer.
Thuya Cretacea, (Heer) Newberry.
Thyrsopteris sp.

These species indicate an age equivalent to the Kootenay or lowest Cretaceous.

Hazelton Group. The beds of this formation overlie the semi-crystalline Kitsalas formation at Mile Post 123 on the railway, and they are the principal rocks exposed along the Skeena and the Bulkley rivers up to Telkwa, the terminal point of the excursion.

The Hazelton rocks are mostly tufaceous in origin, but, unlike those of the Kitsalas, they are well bedded and banded, and are seldom much altered except in the immediate vicinity of intrusive masses. The predominating variety is a heavily banded, bluish grey, rather even grained rock, made up of minute rock fragments usually andesitic in character, with some broken feldspar crystals and occasional angular grains of quartz. Dark argillaceous beds and bands alternate with the tuffs and tufaceous sandstones. These are usually more or less carbonaceous, and in places, carry thin streaks of coal. Conglomerates

made up of well rolled greenstone, occasionally granite and slate, pebbles in a tufaceous cement also occur, but are not common.

The Hazelton tufaceous rocks, while probably mostly deposited in shallow water, were occasionally built up on land. North of Porphyry creek, a heavy band in the series is made up of a confused mass of grey tuffs, which grade into fine and coarse breccias holding numerous rounded andesitic bombs often two feet (.6 m.) or more in diameter. In portions of the region, especially from Moricetown southward along the Hudson Bay mountains, the fragmental volcanics are interbanded with rocks, mostly green, occasionally red, andesites.

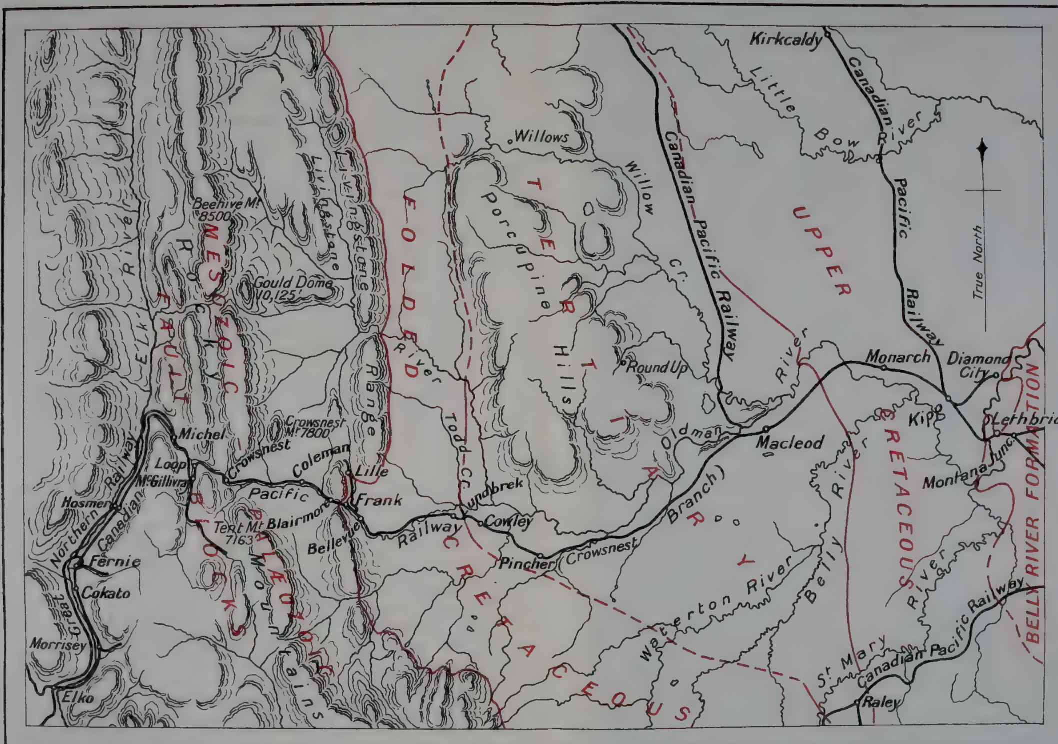
No complete section across the basin occupied by the Hazelton rocks has so far been made. The thickness is consequently unknown, but it is estimated to exceed 4,000 feet (1,219 m.). The beds and associated andesite sheets are occasionally flat, or nearly so, for short distances, but are usually compressed into open, more rarely close, folds, and in places are strongly contorted. Faults are numerous, and in most of the sections the rocks are fissured and traversed by small calcspar veinlets.

Large veins, important for their metalliferous contents, chiefly silver-bearing galena, blende and chalcopyrite, occur in the formation, Several of these are now being explored.

The range in age of the Hazelton formation has not been definitely established. Fossil plants occur in a number of the shaly bands, and a few shells, usually imperfectly preserved, have been collected at several points. These indicate an age ranging from Jurassic up to Lower Cretaceous.

Collections of fossils, made by W. W. Leach from the upper part of the formation and reported on by Lawrence Lambe, include the following specimens.

Belemnites skidegatensis, Whiteaves.
Nerinea maudensis, Whiteaves.
Pleuromya papyracea, var. Carlottensis, Whiteaves.
Astarte carlottensis, Whiteaves.
Trigonia dawsoni, Whiteaves.
Inoceramus concentricus, Parkinson.
Pecten (entolium) lenticularis, Whiteaves.
Pecten carlottensis, Whiteaves.
Thracia semiplanata, Whiteaves.



Route map between Lethbridge and Elko

Kitsalas Formation. The Coast Range batholith is bordered on the east along the Skeena river by a wide belt of volcanics associated with some sedimentary rocks, which have been grouped together as the Kitsalas formation. They are repeatedly intruded by granitic dykes and stocks, and in places, are somewhat schistose, but the alteration is nowhere so complete as in the rocks flanking the batholith on the west. Ordinarily they are greenish to purplish massive rocks spotted with large, rounded, and irregular areas of epidote, and lined along fracture planes with the same mineral.

The formation is made up near the batholith of porphyrites, tuffs, and coarse fragmentals, welded closely together, and seldom showing traces of bedding or banding. Farther to the east, the volcanics alternate with dark and light grey, micaceous sedimentaries. The rocks are everywhere highly altered, in places to such an extent as to obscure their origin, but are seldom conspicuously schistose, except along fracture zones.

The age of the old volcanic complex, represented by the Kitsalas formation, is uncertain. It is older than the Coast Range batholith and is placed tentatively in the Triassic.

Prince Rupert Formation. The Coast range in the vicinity of Prince Rupert is flanked on the west by a wide band of metamorphic rocks, for which the name Prince Rupert formation is proposed. These rocks, originally, were mostly argillaceous, siliceous and calcareous sediments, but have been intensely altered and converted into mica, quartz mica, and hornblende schists, and crystalline limestones. Occasional areas of diorite or gabbro, intruded prior to the folding of the region, are now represented by coarse hornblende schists. West of Prince Rupert, in the western part of Digby island, green chloritic and hornblende schists, derived from fragmental and massive volcanic rocks, occur interbanded with the dark grey, sedimentary schists.

In the section exposed along the railway from Prince Rupert eastward to the western edge of the Coast Range batholith, the limestones and crushed volcanics are absent, and the principal variety is a moderately coarse, well crystallized, quartz mica schist, made up mostly of biotite and angular quartz grains, arranged in alternating lines

and narrow lenses. Some carbonaceous dust is also usually present, and pyrite and garnet are common secondary minerals. In places, there is an alternation of dark grey and light grey bands, the former representing the more micaceous, and the latter, the more siliceous varieties. The degree of crystallization also varies, the rocks ranging from phyllites to fine grained gneisses.

Approaching the granitic batholith there is no notable increase in the crystallization, or in the quantity of secondary minerals present, but aplitic dykes become more common and in the last sections seen, the rocks frequently have a striped appearance due to the intrusion of small acid dykes along the bedding planes, and to the silicification of layers of the schists.

The Prince Rupert schists east of Prince Rupert, have a uniform easterly dip of 30 to 70 degrees towards the granitic batholith, and a N. N. W. strike approximately parallel to the western edge of the batholith. West of Prince Rupert, on Digby island, the structure is more complicated and has not been worked out in detail. The tilting and folding of the beds and the crystallization of the sediments in part, at least, as first explained by Spencer [**6**. p. 19] and confirmed by subsequent observers, probably preceded the granitic invasion.

The age of the schists, while not definitely known, is probably upper Carboniferous, some confirmatory fossil evidence having been obtained by F. E. and C. W. Wright [**8**] in corresponding rocks farther to the north in southeastern Alaska.

Coast Range Batholithic Rocks. The belt of granitoid batholithic rocks which follows the mainland coast of British Columbia and Alaska continuously for nearly 850 miles (1,368 km.) from Fraser river north to latitude 61° N, has a width where crossed by the Skeena river, of 58 miles (93 km.) This long granitic mass, formerly considered to be the product of a single linear invasion, is really made up of a number of batholiths separated in age by considerable time intervals. The intrusions commenced in the Jurassic, and on the evidence of bordering satellitic stocks, probably continued into Lower Cretaceous.

The rocks represented in the line of batholiths range from acid granites to gabbros. The prevailing variety

is a grey medium grained, usually massive, but occasionally coarse, gneissoid rock, intermediate in character between the diorites and granites, and classed generally as a granodiorite. Inclusions of fragments and even large areas of the intruded rocks are common in them.

Along the Skeena river, the Coast Range section is made up of wide bands of light and dark grey granodiorites, alternating with bands of dark basic schists, the largest six miles (9.6 km.) across. The granodiorites in this section show a more or less pronounced gneissic structure everywhere. Along their western margin the schistosity conforms generally in dip and strike with that of the bordering easterly dipping altered sedimentaries. Farther on, the direction and angle of dip varies from point to point, and in a few places the lines of schistosity are sharply plicated. The gneissic structure is considered to have been assumed during the cooling of the granitic magma, and not to be a product of subsequent dynamic deformation.

In the Skeena section there is no clear evidence of more than one period of intrusion, and the granodiorites, except for slight differences in coloration and an occasional banded arrangement due to a concentration of the dark minerals, have a very uniform character across the range. They are medium to coarse grained rocks, occasionally showing a porphyritic texture, made up of a plagioclase feldspar, usually andesine, orthoclase, microcline, quartz, and either or both biotite and hornblende. Apatite, titanite, and magnetite are common accessories, and epidote and, less frequently, pyrite and garnet are conspicuous secondary minerals. The following table by F. E. and C. W. Wright [**8** p. 64] shows the mineral composition of the average batholithic rocks in the Coast range in southeastern Alaska.

Quartz	19·4
Orthoclase	6·6
Andesine ($Ab._{56}$ $An._{44}$)	47·4
Hornblende	7·6
Biotite	11·6
Apatite	·6
Magnetite	·9
Pyrite	·1
Carried forward	94·2

Brought forward	94·2
Titanite	1·3
Epidote	3·5
Chlorite	·1
Calcite	·1
Kaolin and Muscovite	·8
	100·0

This rock is more closely related to the diorites than the granites, and might appropriately be called a quartz diorite or tonalite.

The basic bands included in the granodiorites are made up mostly of dark micaceous and hornblendic schists and fine grained gneisses. They are considered to represent unabsorbed, in places partially absorbed, portions of the intruded rocks, but have been so intensely altered and completely recrystallized that all traces of their original character have disappeared. They often alternate with, or are cut across by bands, of granodiorite, and in some instances have a brecciated appearance due to the number of granitic, aplitic, and pegmatitic dykes crossing them in all directions. Near the basic areas, the granodiorites are usually strongly and regularly banded, the dark bands closely resembling varieties of the included schists.

The basic schists dip at various angles, but in one area are nearly horizontal. The direction of schistosity conforms as a rule with that of the enclosing gneissic rocks.

Aplitic and pegmatitic dykes occur everywhere cutting both the granodiorities and the included schists, but are especially abundant along the western margin of the range. The pegmatite dykes are often of large size, and, as a rule, are very coarsely crystalline. The ordinary constituents are white orthoclase, light pink microcline, quartz, and dark and white mica. Secondary garnets are occasionally present. It is noteworthy that the acid dykes, although belonging to the closing stages of the intrusion, are nowhere schistose themselves. In the western portion of the range they usually cut the schistose granodiorites almost at right angles.

Small basic dykes, younger than the aplites and pegmatites, occur in the range, but are nowhere plentiful in the Skeena section. The common varities are diabases and hornblende lamprophyres.

Intrusives east of the Coast Range. The volcanic and sedimentary rocks bordering the Coast range batholith on the east up to and including the Skeena formation are repeatedly intruded by stocks, some of large size, very similar in mineralogical composition to the batholithic rocks, and classed generally as granodiorites. The ordinary variety is a greyish medium grained, massive rock usually granular in texture, but often becoming porphyritic. Dark diorite and light coloured acid porphyritic phases are not uncommon.

These stocks probably belong to the closing stages of the prolonged period of vulcanism in which the long Coast range group of batholiths was intruded. They cut rocks of Lower Cretaceous age, but are not known to intrude the overlying Tertiary rocks.

Glacial and post-Glacial Deposits. The district at the height of the Glacial period was covered everywhere up to an elevation of about 6,000 feet (1,828 m.) by a great confluent ice sheet. The general movement of the ice east of the Coast range was southerly, but a hugh stream, as shown by numerous strong groovings along the mountain slopes, poured westward to the sea down the valley of the Skeena.

At the close of the Glacial period, the district was depressed, and Skeena valley was occupied by a long arm of the sea which extended through the Coast range into the Interior region. Since then there has been a gradual elevation of at least 500 feet (152.4 m.), the sea has retreated and the mouth of the river has progressed steadily down the valley.

The deposits, illustrative of these changing conditions, consist of boulder clays, estuarine clays, sands and gravels, and fluviatile sands and gravels.

The boulder clays in the lower portion of the valley have been largely destroyed or buried up to Mile post 160, a short distance below the mouth of the Kitsequecla river. Above this point, the valleys of both the Skeena and Bulkley are covered with a nearly continuous irregular sheet thinning out on the ridges and deepening in the depressions. In places, the sheet attains a thickness of over 200 feet (61 m.). The common variety is dark in colour, exceedingly plastic, and thickly packed with scratched boulders and pebbles.

The boulder clays are often overlaid and underlaid, and more rarely interbanded with stratified clays, sands and gravels.

The estuarine deposits, mostly dark, plastic, stratified clays with associated sands and gravels, have been largely destroyed along the valley of the Skeena, and occur only in isolated patches. No fossils were found in them, but similar beds occupying a like position on Bear river at the head of Portland canal contain numerous shells of species still existing in the nearby ocean.

The estuarine deposits, and the boulder clays along the central portion of the valley, are overlaid by river sands and gravels. The older deposits were cut through as the land rose and the river deepened its channel, and now occur on benches at various elevations above the water level up to at least 300 feet (91.4 m.).

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ANNOTATED GUIDE.

PRINCE RUPERT TO TELKWA.

The route of the excursion lies over a completed or nearly completed section of the Grand Trunk Pacific railway from Prince Rupert to Telkwa, a distance of 235·5 miles (378·9 km.). The Skeena river and its tributary, the Bulkley, is followed throughout.

Geological Survey, Canada

Route map between **Prince Rupert** and **Telkwa**

Miles

5 0 10 20 30

Kilometres

5 0 10 20 30 40 50

Prince Rupert.—Prince Rupert is at present a straggling town of about 5,000 inhabitants, but has hopes of some day becoming a great world port. It possesses a magnificent harbour, and is the Pacific Coast terminus of the Grand Trunk Pacific railroad, the shortest route to the Orient. It is at present the centre of large and thriving fishing and lumbering industries, and its northerly situation places it in a position to control the trade both of the Yukon and the great interior region of northern British Columbia. This trade is comparatively small at present, but must rapidly expand with the settlement of the country and the development of the mining industry.

Leaving Prince Rupert, the railroad partly rounds Kaien island, and at Mile 7, crosses to the mainland, where it follows up the bold northern shore of the island-filled estuary of the Skeena. On the left are the low Porpoise islands, and farther on, Smith island, a wooded mountain block rising steeply from the sea, is passed.

The rocks along this part of the route consist of the greyish, easterly dipping, quartz mica, and hornblende schists of the Prince Rupert formation, intruded by a few granitic dykes and stocks. They are traversed by numerous small quartz and quartz-calcite veins, and, in places, are spotted with small garnets. These rocks are well exposed in the vicinity of Prince Rupert, and in long cuts all along the railway.

Mile 16.—The last exposure of the Prince Rupert schists occurs at this point. They are here in close proximity to the Coast Range batholith, and in places have a striped appearance, due to the intrusion of small aplitic dykes and to the partial silicification of thin bands parallel to the bedding planes.

The actual contact between the schists and batholithic rocks is concealed along the railway.

Mile 16·7.—Sockeye.—Immediately west of Sockeye station coarse gneissic granodiorites occur, and these rocks, the main component of the batholith, are exposed at intervals for many miles eastward.

Mile 17·5.—Good sections of the gneissoid granodiorites occur at this point. They are cut by numerous light coloured aplitic dykes and by large, coarse textured pegmatite dykes often with an aplitic border. The dykes are not all contemporaneous, as they are frequently found cutting each other, and are occasionally faulted.

Mile 36 to 39.—The granodiorites in this stretch are mostly replaced by dark micaceous and hornblendic schists, probably highly altered inclusions, cut by numerous dykes. East of the basic schists, the granodiorites are banded for some distance, and contain frequent dark patches.

The Skeena River valley opposite Sockeye and eastward to Port Essington, Mile 24, is wide and filled with brackish water. Above this point, the valley narrows and a gradual change from estuarine to river conditions is noted. The sediment brought down by the river is mostly deposited in this stretch of slackening current, and long sand bars are slowly emerging above the surface. Farther up these are replaced by low wooded alluvial islands. The effect of the tides is felt up to Mile 60.

The bordering mountains, usually from 3,000 to 4,000 feet (914 to 1,219 m.) in height, are wooded nearly to their summits, and crowd closely down to the water's edge. There are few intervening flats, except at the mouths of tributary streams.

Mile 44·9.—The Kwinitsa river, a small stream, enters the Skeena at this point, and the junction is marked by a large flat built of alluvial sands, silts, gravels and clays. One of the gravel beds a few feet below the surface, is saturated with brine. The brine is considered to be imprisoned sea water, somewhat concentrated, left behind during the retreat of the sea in post-Glacial times. The Skeena water opposite this point, although affected by the tides, is now quite fresh.

Mile 46 to 48.—A second band of dark basic schists is crossed at this point, and the bordering granodiorites are banded light and dark grey for some distance to the east.

Mile 48 to 68.—This section may be considered the heart of the Coast range. The mountains, while not high, are steep, boldly sculptured, and in places singularly impressive. Opposite the the Exstew river a number of small glaciers are seen south of the valley, clinging to the upper levels of the range. They occupy a wide cirque-like depression probably excavated by themselves. The glaciers here as elsewhere in the range are slowly dwindling.

The trough shaped valley of the Skeena is seldom less than a mile in width, and the river, split into a multitude

of channels, swings from bank to bank washing alternately the slopes on either side.

The valley bottoms are flat and built of alluvium, and there is a marked absence all across the range of boulder clay and other deposits of the Glacial age. These have either been destroyed or buried beneath recent river accumulations.

Mile 68 to 74.—A wide band of crystalline schists, the widest in the range, occurs at this point. The dark micaceous schists occur in bands, occasionally broken and brecciated, and in lenses alternating with striped and banded gneisses. Aplite and pegmatitic dykes, cutting all the varieties, occur in places, but are not so numerous as in the western part of the range. The schistosity here is often flat or in easy folds.

Mile 83.—The eastern border of the main Coast Range batholith is crossed at this point. Its junction with the bordering rocks of the Kitsalas formation is concealed along the railway.

Mile 83 to 91.—Almost continuous exposures of the rocks of the Kitsalas formation are displayed in the numerous cuts along this stretch. The rocks are largely of volcanic origin and include porphyrites, andesites, and altered tuffs and breccias. They show considerable fracturing, but are only rarely crushed into schists. A feature of the formation is the extensive development of epidote in rounded and irregular kernels and along fracture planes. Granitic dykes are numerous.

Mile 91.—The Coast Range mountains gradually decrease in height from Mile 86 eastward, and at Mile 91 a wide valley occupied north of the Skeena by the Kitsumgallum river is reached. This great depression, four miles in width where crossed by the Skeena, traverses the country in a north and south direction, completely piercing the Coast range, and is evidently of great age, long antedating the initiation of the present drainage system. Its origin and history have not been worked out. North of the Skeena, the valley is floored with heavy deposits of sand, loose gravels and clays, post-Glacial in age and partly marine in origin.

A change in the character of the Skeena River valley is noticed after passing the mouth of the Kitsumgallum. Below this point steady deposition has been going on since the retreat of the sea, and the valley bottom is a maze of

low alluvial flats and islands. The few terraces present have been mostly built up by detritus brought down by tributary streams. Above the Kitsumgallum, the river is engaged in scouring out its old channel partially filled up by over sedimentation during the closing stages of the Glacial period.

Mile 95·2 to 104.—East of the Kitsumgallum river the Kitsalas volcanics are replaced for some miles by granodiorites, often porphyritic in texture. These rocks are precisely similar in mineral composition to those in the main Coast Range batholith, and may be a spur from it. They are not schistose, but are strongly jointed and, in places, have a columnar appearance due to the intersection of two sets of jointage planes. They include numerous fragments of the neighboring dark rocks, and are cut by acid dykes and by a later group of coarse basaltic dykes.

Mile 104. Kitsalas Canyon.—The Skeena river here forces its way through the narrow rock-walled Kitsalas canyon, one of the most picturesque points in its course.

The canyon is about a mile in length, and in places, scarcely 100 feet (30.4 m.) in width, and is sunk through the greenish and greenish-grey volcanics of the Kitsalas formation, the junction of these with the granites occurring near its foot.

The origin of the canyon is plain. The valley here at the close of the Glacial period, when the Coast region was depressed, was filled with estuarine clays, sands and gravels to a height of 170 feet (51.8 m.) above the present water level. On the retreat of the sea the river commenced cutting down through these, and the canyon marks a reach where the new channel deviated from the old one, and crossed a buried spur from the bordering mountains.

In passing Kitsalas canyon the roughness of the ground necessitated the construction of four tunnels on the railway, one through a clay ridge.

Mile 105 to 112.—Occasional cuts along the railway expose the rocks of the Kitsalas formation. They are more schistose than farther west and in places resemble the Prince Rupert altered sedimentaries.

Mile 113.—A long cut across a low terrace at this point exposes estuarine clays and sands overlaid by river wash.

Mile 113·5 to 122·9.—A second large stock of massive grey granodiorite, intruded through the rocks of the Kitsalas formation, is crossed in this reach.

The mountains bordering the valley from Kitsalas canyon eastward to this point and for some distance beyond, are considered to be a northerly spur from the Coast range. High snowy peaks and steep serrated glacier-laden ridges are seen south of the valley up gashes cut by tributary streams.

Mile 122·9.—The semi-crystalline volcanics and associated sedimentaries of the Kitsalas formation reappear at this point east of the granodiorite stock, but are soon overlaid by the banded tuffs of the Hazelton formation.

Mile 123·45.—The first section of the rocks of the Hazelton formation occur at this point. They consist of dark tuffs, alternating with black, fine-grained carbonaceous bands, also tufaceous in character, and sheets of green andesite. The rocks are folded, and are often broken and faulted, but are much less altered than those of the underlying Kitsalas formation.

Similar banded rocks, varying somewhat in texture and colour and occasionally including some conglomerates, are exposed at intervals eastward to Skeena Crossing. The undulate as a rule in easy folds, but in places are steeply tilted, violently flexed and broken. They are cut by a number of diorite porphyrite dykes and small stocks of granodiorite.

Mile 131.—The Skeena passes through a short canyon at this point walled with massive bands of grey tuffs and dark carbonaceous shale. The valley is wide, with a terraced central portion bordered by rocky ridges rising farther back into mountains.

Mile 139·5.—East of the river is Minskinish, a well built Indian village, and behind it, rises a picturesque group of high peaks known as the Seven Sisters, built mostly of the upturned rocks of the Hazelton formation intruded by a granitic stock. These mountains are placed in the Interior region, although they are not separated from the Coast Range mountains by any marked depression.

Mile 143·5.—Tufaceous beds of the Hazelton formation pass into conglomerates made up of well rolled pebbles of greenstone with some granite and slate in a tufaceous matrix.

Mile 145·4.—A section exposed at this point shows a heavy conglomerate band associated with tufaceous sandstones.

Mile 147·3.—Immediately beyond Ksi-den creek the railway enters a tunnel piercing a narrow gravel plateau. A strong riffle occurs here in the Skeena river, above which the valley opens out into a wide irregular terraced plain.

Mile 149·4.—Sections at this point show soft, light colored, tufaceous sandstones interbedded with dark shales.

Mile 152·2.—The Kit-wan-cool river, which is crossed at this point, occupies, like the Kitsumgallum, a wide north and south depression extending from the Skeena north to the Nass.

Mile 156·1.—The Hazelton beds are here intruded by large altered and fissured diorite porphyrite dykes.

Mile 161·05.—Sections of dark plastic boulder clay are here seen for the first time in ascending the valley.

Mile 163·4.—The Kitseguecla river, deeply trenched in a long canyon, enters the Skeena from the south. East of it is the Rochers Déboulés range, a long mountain mass breaking in places into high pinnacled peaks and sharp crested ridges.

Mile 164·2.—**Skeena Crossing.**—The railway, which has hitherto followed the left bank of the Skeena, crosses to the right. The river here and for some distance above and below occupies a deep gorge sunk through the drift into the underlying rocks, and a long bridge has been thrown across this at an elevation of 140 feet (42·6 m.) above the water level.

The rocks of the Hazelton group, consisting here of alternating bands and beds of grey, tufaceous sandstones and dark, usually carbonaceous, shales, cut by occasional diorite porphyrite dykes, are well displayed in the walls of the gorge. They have yielded unequally to compression, and sharp bends often accompanied by faulting alternate with long easy folds.

Terraced Skeena valley above Hazelton.

East of Skeena Crossing the railway follows a wide roughly terraced slope, which intervenes between the river and the bordering Rochers Déboulés mountains. The older rocks are mantled everywhere and in places deeply buried beneath, a thick covering of glacial drift.

Mile 175.—A small granitic stock more basic than usual, intrusive into the Hazleton beds, crosses the valley.

Mile 176.—Seely gulch a deep V-shaped gorge, sunk through boulder clay, joins the Skeena from the south.

Mile 177.—Hazelton.—The railway leaves the Skeena at this point and turns to the right up the Bulkley a tributary stream. Both rivers near their junction, have cut deep, terraced, secondary valleys through the drift, Looking northward from the railway level 320 feet (100 m.) above the river, the great mountain-bordered valley of the Skeena is seen stretching far into the distance. Hazelton, an old furtrading post of the Hudson's Bay Company and at present the principal trading centre of the district, is situated in the foreground at the confluence of the two rivers.

Mile 180·5.—New Hazelton is situated in a wide flat separated from the river by a rocky ridge, and a road leads from it to old Hazelton, across the Bulkley, which is here enclosed in a rocky gorge. A good view of the Rochers Déboulés mountains on the southwest is obtained from this point.

Rochers Déboulés mountains, from the junction of the Skeena and Bulkley rivers.

Mile 183·5.—The railway, which, since leaving Mile 178, has followed a terraced flat south of the river approaches and joins it here, and for some miles skirts closely the edge of the wild canyon in which it is enclosed. The walls of the canyon, usually over 200 feet (60·9 m.) in height, show almost continuous exposures of the undulating and in places crumpled and broken, strata of the Hazelton formation. Boulder clays in heavy ridgy sections overlie the older rocks, and are pierced in three placed by tunnels.

Mile 186.—A boulder clay plateau, 75 feet (22·8 m.) in height above the grade of the railway, and 300 feet (91·4 m.) above the river level, is pierced by a tunnel 2,016 feet (614·4 m.) in length. Southwest of the tunnel, the deep, winding, rocky gorge of the Bulkley is seen to advantage from the railway grade.

Mile 188.—A deep cut exposes the boulder clay at this point. Boulder clays often associated with sands, clays and gravels are prominent in most of the sections along this portion of the valley.

Mile 190·9.—Here the deep valley of Mud creek, sunk through boulder clay, is spanned by a high bridge.

Mile 193.—Long sections of greyish coarse tuffs and volcanic breccias holding numerous rounded andesitic bombs, occur at this point and are underlaid in places by the dark tufaceous sandstones characteristic of the Hazelton group.

Mile 193·5.—The coarse grey fragmentals are cut by an altered andesitic dyke 120 feet (36·5 m.) in width. The dyke probably belongs to the same period of vulcanism as the band of ejectamenta it cuts.

Mile 193·9.—The tuffs are overlaid by a massive band of green andesite showing brecciation in places.

Mile 195·9.—North of Porphyry creek the green andesitic flow rocks are cut by a white, yellow weathering, altered intrusive filled with pyrite. This rock represents a contact phase occurring at the termination of a large granodiorite stock which extends to the northeast.

Mile 196·3.—Sections of green andesite, brecciated in places and occasionally holding greenstone fragments, are exposed at this point.

Mile 198·9.—Boulder creek is crossed on a high bridge.

Mile 202·1.—The beds of the Skeena formation (lower Cretaceous) occupy a basin extending along the

Canyon on the Bulkley river.

railway from Mile 197 to about Mile 204. Good sections of these beds occur in a railway cut at this point.

The Skeena beds overlie those of the Hazelton formation, apparently comformably, although this has not been definitely proved. They consist of felspathic sandstones, indurated clays, carbonaceous shales, conglomerates and occasional beds of coal. They are folded, but not so severely as the Hazelton beds, and do not show the same persistent fracturing and veining.

Mile 206·8.—Looking up the valley of Two Mile creek a good view is obtained of the imposing mass of peaks streaked with snow fields which form the southern end of the Rochers Déboulés mountains. The highest peak reaches an elevation of 8,100 feet (2,468 m.).

Mile 210.—Moricetown.—A short box canyon occurs on the Bulkley at this point. The canyon is sunk through a sheet of andesite bent into an anticline. Half a mile beyond Moricetown are sections showing green andesites streaked in places with black areas.

Mile 213·3.—Interbanded green and red andesitic rocks of the Hazelton group are exposed here. The green variety represents flow rocks. The red variety consists largely of fine grained andesitic tuffs and in places is cleaved into slate.

Mile 214·2.—Sections of the ordinary dark tufaceous sandstones and shales of the Hazelton group occur here. Some of the beds are highly fossiliferous, especially along the Bulkley river a mile east of the railway track, to which point a collecting trip will be made if time permits. The fossil beds so far have only been hastily examined.

The railway at this point passes along a steep slope at an elevation of 190 feet (57·9 m.) above the river, and affords a good view of the rough, partially terraced valley of the Bulkley, here from four to five miles (6·4 to 8 km.) wide. The valley on the east is bordered by a long worn ridge overlooked by the partially snow-clad peaks of the Babine range.

Mile 214·4.—The Hazelton beds here are intruded by a small light coloured quartz porphyry stock.

Mile 214·5.—Beyond Trout creek the river bends to the east and the railway follows up Toboggan creek, a small stream fed from a glacier in the Hudson Bay mountains, the bordering range west of the valley. The valley in this portion of its course is covered thickly with

drift, mostly boulder clay, and few rock sections are exposed.

Mile 225.—Kathlyn lake, a shallow sheet of water about a mile in diameter occupies a depression in the boulder clay. To the west are three prominent peaks of the Hudson Bay mountains separated by deep valleys filled in their upper reaches with ice.

Southeast of Kathlyn lake, the railway follows a boulder clay plain separated from the river by a low ridge.

Mile 230.—At this point the railway rejoins the Bulkley river, which it follows to Telkwa. The Bulkley here winds through a wide secondary valley sunk through the drift and bottomed with large alluvial flats.

Mile 235·51.—Telkwa.—The Telkwa river, a swift turbid glacial stream, here joins the clear Bulkley. Both streams approach their point of junction through short canyons, having sunk their channels through the drift into a low rock plateau, probably a ridge in the floor of the old valley.

Sections of the bluish grey, felspathic sandstones and carbonaceous shales of the Hazelton group are exposed along the canyons.

Telkwa the terminal point of the excursion is situated east of the Bulkley river opposite the mouth of the Telkwa river.

EXCURSION C 8.

YUKON AND MALASPINA.

CONTENTS.

GENERAL INTRODUCTION

BY

D. D. CAIRNES.

Excursion C 8 includes the trip from Prince Rupert to Skagway, Whitehorse, and Dawson, and the return journey via Skagway, Juneau, Glacier bay, Yakutat bay, and Prince Rupert to Vancouver.

The trip from Prince Rupert to Skagway, along the fiord-indented, island-strewn coast of southeastern Alaska is most picturesque. The effects of glaciation, past and present, are there strikingly illustrated, and toward the north a number of glaciers extend to the water's edge and may be viewed at close range from the steamer. The distance from Prince Rupert to Skagway is about 460 miles (740 km.).

From Skagway to Whitehorse, a distance of 110 miles (177 km), the journey is made by the White Pass and Yukon railway. From Skagway the train commences almost immediately, a steady climb up the wild, rugged, granitic mountains of the Coast range, proceeds over the White Pass summit, thence runs along various small lakes and streams to Lake Bennett, and continues along its shores to Caribou, 68 miles (109 km.) from Skagway. For this distance, the train follows very closely the general route pursued by the early stampeders in their mad rush to the Klondike in 1897 and 1898. From Caribou northward the train follows a broad depression for about 30 miles (51 km.) until suddenly Lewes river comes into sight from the east and a good view is obtained of the famous Miles canyon, where so many daring adventurers have lost their lives. The railway in the last few miles has a steep grade, descending rapidly to the banks of Lewes river at Whitehorse, near which are situated the Whitehorse copper deposits.

From Whitehorse to Dawson the journey is made by steamer down Lewes and Yukon rivers, a distance of about 460 miles (740 km.). This trip, made on one of the commodious steamers plying these waters during the summer months, is one of exceptional beauty and is of particular

interest to the physiographer and glacial geologist, as in this distance one passes gradually from a region near the inner edge of the Coast range where glaciation has been intense, well out into a portion of the Yukon plateau where no evidence of glacial ice can be detected. Among the more interesting points or features along the route are Lake Laberge, Thirtymile river, Tantalus coal mine, Five Fingers rapids, and Rink rapids.

After spending three days in the vicinity of Dawson, in the Klondike gold fields, the excursion will return to Skagway. Stops have been arranged along the route to allow the excursionists to visit Tantalus coal mine and Whitehorse copper deposits.

From Skagway to Juneau, a distance of 125 miles (200 km.) the journey must be made by steamer, and while at Juneau facilities will be afforded for visiting the great Treadwell mine in the vicinity.

From Juneau members of the excursion may either return to Vancouver or continue northwesterly along the Alaskan coast to Yakutat. Those proceeding to Yakutat will spend two days in Yakutat bay, where they will have an opportunity of studying existing glacial phenomena, among them the great Malaspina glacier and the deposits being formed in places along its front, and will be able to see clearly from the steamer the various other important ice bodies along the coast between Juneau and Yakutat.

The return journey from Juneau to Vancouver will follow, as on the way north, the picturesque inland passage along the coast.

For convenience in description, C 8 excursion is divided into three sections as follows:—

1. Prince Rupert–Skagway section.
2. Skagway–Whitehorse–Dawson section.
3. Juneau–Yakutat section.

The descriptions of C 8 excursion are arranged under the above headings.

PRINCE RUPERT—SKAGWAY SECTION

BY

FRED. E. WRIGHT.

PHYSIOGRAPHY AND GEOLOGY.

The geologic and geographic features which are characteristic of the coast from Vancouver to Prince Rupert continue northwestward with slight change to Skagway. To the east, the Coast Range batholith or batholiths extend in an unbroken line from Vancouver northwestward for over 1,000 miles (1,600 km.) and average nearly 100 miles (160 km.) in width. The major structures of the intruded rocks follow the trend of the Coast range, especially from Wrangell to Skagway. The geology throughout the region is on a broad scale, the different formations often continuing for many miles either without perceptible change or with a continuous and progressive change which can be readily followed.

The island group along the coast, which constitutes the Alexander archipelago, is considered to be the southerly extension of the Mount St. Elias range, while the shore of the mainland belongs to the western flank of the Coast range. This separation by Brooks of the island group from the mainland is in accord with the classification of Dawson in British Columbia, where the Vancouver range is clearly distinct from the mainland Coast range. Although rugged and mountainous in the extreme, this portion of southeastern Alaska is so profoundly intersected by narrow arms of the ocean that communication by water between nearly all parts of the region is feasible and easy. This web of waterways, spread over the entire area, affords deep sea craft access to points far inland, and is of great economic importance. The fiords are not only of value as highways of commerce, but they are a great commercial asset because of the immense quantities of fish—salmon, halibut, and herring—which throng their waters at different seasons of the year. The peculiar and unusual combination of deep narrow fiords and high towering mountains, heavily covered along their bases with dense forests of spruce, hemlock, and cedar, in contrast to their glacier and snow-clad peaks and domes, produces tremendously impressive scenery, and appeals alike to traveller and native

To the former, however, the abundance of rain in this region is an inconvenience and often depressing, but, once this condition is accepted, the superb scenery is in itself ample reward for the journey.

The characteristic surface features of this belt are its coasts, its fiords, its valleys, its drainage, its glaciers, and its mountains. The coasts are irregular in outline and generally abrupt and mountainous even to the water's edge. Occasionally, however, low lying forelands fringe the base of the mountains, as at Gravina island, and often extend as a reef for some distance from the shore, where they become a menace to navigation. In the Glacier Bay region submerged tree trunks prove that the coast is sinking relatively to sea level, while on Admiralty island recent fossils have been found in a bed of blue clay 200 feet (60 m.) above tide water, thus indicating a rise of the coast since the recession of the ice. It would appear, therefore, that the coast has undergone both positive and negative changes since the Glacial epoch. The coasts are generally heavily covered with dense forests which, notwithstanding the lack of proper subsoil which was entirely removed by the ice, are so thick and luxuriant that the geologist is forced to confine his reconnaissance study of the region to the immediate shore outcrops between high and low tide water marks and to the uplands above timber limit, 2,000 to 3,000 feet (600 to 900 m.) above tide water. The fiords are deep and are characteristically trough-shaped. Their flat floors are in places cut below grade in their central portions and relatively shallow near their mouths, and are soft and evidently covered with glacial débris. The best halibut fishing is found on these terminal submerged sandbanks. Many of the fiords are remarkably straight and trend either in a northerly or a northwesterly direction. The longest fiord is Chatham strait with its inland extension, Lynn canal. It is about 250 miles (400 km.) long, 3 to 6 miles (5 to 10 km.) broad, with a depth of 1,000 to 2,500 feet (300 to 750 m.), and traverses the general trend of the bed rock structure at an angle of about 30 degrees. Both the topography and geology indicate that it owes its position to a great structural fault. Many of the other fiords also follow structural lines in the bed rock formations. Other important fiords are Portland canal, Clarence strait, Behm canal, Taku inlet, Glacier bay, Icy strait, and Cross sound. The evidence at present available indicates that practically all the fiords are simply

old valleys which, during the ice-flood period, were profoundly modified, the glacial erosion extending far below sea level, widening the valley, aligning its walls, and smoothing them out into wide sweeping curves; in brief, sculpturing the land into forms in harmony with the stiff, non-pliable nature of the eroding ice streams confined within the valley. As a result, the topography bears everywhere the marks of most intense glaciation. Of the distinctive features of glacial erosion on a tremendous scale, the following are characteristically developed in Southeastern Alaska:—U-trough shape of cross section of valley; straightening of valley course; glacial grooves and markings along valley sides and bottom;; steep valley head, often with cirque termination; hanging valleys; steep valley walls, in places overhanging and showing double slopes; alignment of cliff bases; glacial junction spurs; grade of valley floor, in places overdeepened; knolls of bed rock projecting above the valley floor; roches moutonnées, etc. The noticeable absence of moraines in this area of intense glaciation is due chiefly to the peculiar steepness of the mountain and valley slopes, which are often oversteepened and so uneven, that, except for the river deltas and flats, it is difficult to find a flat area a single square mile in extent in all the 40,000 square miles (100,000 sq. km.) of land area in Southeastern Alaska.

The fiords pass at their heads over broad tidal flats into wide floored valleys, densely forested, and exhibiting everywhere profound ice erosional features. The valleys in turn are usually terminated by cirques in which a small glacier may still be present, the original glacier, which filled the valley to a depth of 4,000 to 6,000 feet (1,200 to 1,800 m.) having dwindled to the present miniature glacier, which is ineffective and incapable of accomplishing the prodigious feats of erosion which it performed during the ice deluge. Farther to the north and west, in Glacier bay and Yakutat bay, the glaciers are larger and more impressive, but, compared with the great ice masses which were active during the period of maximum ice extension, they are mere pigmies. The land forms over the entire area indicate an intensely glaciated region which has been but slightly modified by water erosion since the Glacial epoch. At the time of maximum ice flooding, the ice sheet covered the whole archipelago with the exception of isolated high peaks, which can be recognized at present as having been above the ice sheet, by their sharp serrated

outlines and lack of glacial rounding. The sand banks off the coast indicate that the ice extended even on and into the ocean for some distance from the coast.

Rivers and streams are abundant in this region, and, although in general short and draining relatively small areas, they are of large volume during the summer months because of the excessive precipitation and the melting of the snow in the mountains. Several of the rivers, notably the Stikine, Taku, Chilkat, and Alsek, rise in the interior plateau country beyond the Coast range and are evidently antecedent to it in character. The Stikine river is navigable up to Telegraph Creek, British Columbia, 170 miles (273 km.) from the coast. Most of the rivers enter salt water at the head of a fiord, but many streams from tributary `hanging valleys terminate as waterfalls, plunging 1,000 feet, (300 m.) more or less, down the walls of the master valley and adding greatly to the charm of the landscape. Many of these waterfalls are the outlets of lakes hidden behind the bed-rock lip of the hanging valley, and such streams may well serve later on for the commercial development of power for different purposes.

Southeastern Alaska is essentially an upland area of high relief, deeply dissected by valleys and canyons. The uplands slope in general toward the Pacific, and exhibit in places a tendency toward uniformity of their summit levels, which there have the appearance of an uplifted, warped, and much incised base level of erosion. They have been so interpreted, but there are certain objections to this simple hypothesis of an elevated peneplain which have not been entirely removed and will have to be met before it can be finally accepted. It is possible that both the observed tendency toward planation in the uplands and also in the forelands noted above, owe their present character to ice action. It is significant in this connection that the upper limit of ice action coincides with the upland base level. If the ice sheet remained long enough at approximately the same level its surface might well have functioned, like a large water surface, as a datum plane toward which the exposed land masses tended to be bevelled. Sufficient evidence has not yet been gathered to determine definitely the role, which such ice-cap beveling may have played in the formation of the observed upland surface.

The structure of Southeastern Alaska is exceedingly complex, and has been studied at relatively few points.

It includes rock formations representing nearly all the geologic periods from early Paleozoic to the present. The Paleozoic rocks have passed through several periods of folding and metamorphism, and show clearly the effects of such treatment. They are in places so intensely metamorphosed and intricately folded, that it is not possible to disentangle all the details of their structure; even to decipher their broader features is in many instances not easy. In general the formations strike parallel with the northwest trend of the mountain range, and this produces a zonal arrangement of the broader features of the areal geology. In the different formations, we find interbedded with one another, black slates, argillites, greywackes, crystalline schists, crystalline limestones quartzites, greenstones, and chlorite- and amphibole-schists. The intrusive rocks consist chiefly of granular diorite and granite types. They constitute the great batholithic core of the Coast range, and dominate it both structurally and petrographically. They also cover large areas in the central portions of many of the islands.

The Coast Range batholith is bordered on the west by a band, several miles wide, of closely folded crystalline schists, composed largely of Carboniferous and Mesozoic strata. They have been termed the Ketchikan series by Brooks in the Ketchikan district, while in the Juneau district they are grouped together as the "schist band" by Spencer. They have been traced from the southern boundary of Southeastern Alaska to its northern boundary at the head of the Chilkat basin. These strata are essentially siliceous mica-schists and argillites, feldspathic schists with intercalated amphibole—and chlorite—schists, and occasional belts of crystalline limestone containing Carboniferous fossils. Narrow outlying belts of the Coast Range intrusives invade these schists and have often altered and recrystallized them to such an extent near the contacts that they are now massive gneiss, and it is not everywhere possible to distinguish with certainty the boundary line between the intrusive and the intruded rocks. This is especially true along the margin of the mainland Coast Range batholiths, where, in addition to gneissoid structure, the rocks are cut by an intricate network of pegmatite dykes and quartz veinlets. In the Ketchikan district this type of contact prevails, the effect of the intrusive extending often for 10 miles, (16 km.) and more out from the contact. Away from the contact, the

beds become less schistose, and "black slates" intruded by altered dykes of andesitic and gabbroic rocks, predominate. The latter are more prominent in the Juneau district than to the south. At a distance from the Coast Range batholith, intercalated beds of altered lavas and tuffs, usually called greenstones appear; still farther from the contact great thicknesses of these greenstones occur. Such belts of massive greenstone beds are well exposed along Tongass narrows at Ketchikan, along the west side of Cleveland peninsula, on Glass peninsula, and on the west side of Douglas island.

Beyond this belt and toward the outer coast, the bed rock structure changes with the latitude, and beds of one formation cannot be traced for any great distance northwesterly as can the rocks along the mainland. This is largely due to the irregular island batholithic intrusives noted above.

The sedimentary rocks flanking the Coast Range batholiths in this region are folded closely near the contact and more openly at a distance, so that, though their general trend is parallel to the range, their dip is extremely variable, ranging from northeasterly to southwesterly at all angles. These dips become more constant, however, toward the north in the Wrangell and Juneau districts, where the schists are more typically developed, where mineralization along certain bands is more pronounced, and where sharp and closed and overturned folds appear to be the rule. The prevailing dip there is steeply northeast into the mountains, and the strike parallel with the range.

In Southeastern Alaska the oldest rocks are apparently a series of fragmental rocks, now represented by banded quartzite, chert, sandstone conglomerate, and some tufaceous material. These clastic rocks grade upward into calcareous beds and limestones containing Silurian fauna. The total thickness of these beds is 10,000 feet (3,000 m.) or more. Sedimentation was probably continuous during early Silurian time. Toward the end of the period there was then a gradual deepening of the sea, and several thousand feet of limestone strata were laid down. The oldest member of the Devonian is a succession of conglomerate and sandstone beds composed largely of igneous material, the pebbles of the conglomerate being embedded in a tufaceous matrix and derived chiefly from the older banded quartzite-limestone strata. This series,

which is estimated to be 3,000 feet (900 m.) thick, grades upward with apparent conformity into lower Devonian limestones, the total thickness of which is about 2,000 feet (600 m.) These are followed in certain areas by argillaceous schists and slaty limestones, and these, in turn, by upper Devonian limestone of considerable thickness. The close of the Devonian period was marked by volcanic activity along this coastal belt, and lavas and tuffs to an estimated thickness of about 800 feet (250 m.) were laid down. During the Carboniferous period, limestones and argillites were again formed, and volcanic activity began again in upper Carboniferous times and continued well into the Mesozoic era. Many of the altered massive greenstones and greenstone schists date from this long period. The beds of lava and ash, ejected from the volcanic vents, were contemporaneous with the slate beds, and because of their intimate association with the sediments the volcanics are regarded as submarine intrusives. Their total thickness, including the slates, is estimated at 4,000 feet (1200 m.) During Mesozoic times the sequence of geologic events has not been definitely determined because of lack of proper evidence, and geologists do not agree in their interpretation of the few observed facts. The evidence is at best fragmentary, and indicates that, following the deposition of Carboniferous and early Mesozoic strata, the bedded rocks suffered intense metamorphism and at the same time were highly tilted and intricately folded and rendered schistose, the direction of the axes of folding and of the schistosity being generally southeast-northwest. Immediately following this period, and possibly in part concomitant with it, occurred the invasion of the Coast Range batholiths, whose lines of intrusion are in a broad way parallel to the schistosity and bedding planes of these older rocks. The Coast Range intrusives probably began early in Jurassic times, and continued either to upper Jurassic or lower Cretaceous times. During the lower Cretaceous, calcareous slates were deposited, after which a period of uplift and folding followed. In the early Tertiary, the Kenai (Eocene) coal-bearing beds were deposited in isolated local basins in this region, but they are not of commercial importance. They occur only near sea level and in low-lying valleys and basins practically enclosed by mountains of older rocks. Flat lying Tertiary basalt lava flows occur here and there and attain a thickness of

1,500 feet (450 m.) on Kuiu island. A large part of the Tertiary sediments may have been subsequenly removed by erosion. The next important event in the geologic history was the development of the ice sheet which covered the entire district. Its retreat left the topography in essentially the present form. After the retreat of the ice some basaltic sheets were locally erupted.

In this brief sketch of the geologic history of Southeastern Alaska many details have been omitted, but many more details are still required before the history can be written with even a first approach to completeness. Many of the conclusions reached are still tentative and merely the best that can be drawn from the existing evidence. On the accompanying maps only six subdivisions are recognized, the entire Paleozoic being grouped as a unit; likewise the Mesozoic, the Tertiary, and the Quaternary. It should be noted that the greenstone black slate series apparently includes formations ranging from upper Carboniferous to Jurassic in age. This finds expression in the term "Vancouver series" which is used in British Columbia.

Miles and Kilometres

ANNOTATED GUIDE.

0 m.
0 km.

Prince Rupert.—After leaving Prince Rupert and passing Dundas island on the left, and Port Simpson, 25 miles (40 km.) on the right, the route of the excursion enters Dixon entrance and crosses the International Boundary line into Southeastern Alaska. On the right is Portland inlet and Portland canal, one of the largest fiords on the Pacific Coast. Portland canal cuts almost entirely through the Coast Range batholith and extends practically to its eastern flank. Mineral deposits have been discovered along this eastern contact of the batholith in Canadian territory both at the head of Portland canal and near Observatory inlet. Several bands of sedimentary rocks, included in the Coast Range batholith, are also heavily mineralized and promise well as ore producers.

Dixon entrance is one of the few exposed parts of the inland passage, and at certain times

Miles and
Kilometres

of the year is rough and choppy. Once inside of Duke island and in Revillagigedo channel, however, the sweep of the waves and winds is broken, and quiet waters again prevail.

31 m.
50 km **Cape Fox**.—Cape Fox and the adjacent mainland peninsula opposite Duke island consist largely of massive and schistose greenstone beds with occasional calcareous and argillaceous bands. These strata were formed either at the end of the Carboniferous or in the early Mesozoic. At present they are so highly altered that their original character is rarely apparent without detailed study. The same belt, though slightly different in composition, continues northward to Ketchikan and beyond.

62 m.
100 km. **Annette Island**.—Annette island on the left is interesting, because of the development of the forelands which fringe its shores, and which have been considered by Gilbert to indicate a secondary base level of erosion in the physiographic development of this region. Annette island has been set aside as a reservation for the Indians at Metlakatla under Rev. Duncan.

78 m.
125 km. **Tongass Narrows**.—Along the shore of Tongass narrows, greenstones with interbedded argillaceous and calcareous rocks in various stages of metamorphism are exposed.

80 m.
130 km. **Ketchikan.**—Ketchikan is the centre of the Ketchikan mining district in which copper and gold are the principal metals mined. Mining operations are confined chiefly to Prince of Wales island.

93 m.
150 km. **Clarence Strait**.—Entering Clarence strait the route continues northward to Zarembo island. 161 miles (260 km.) whence it passes across Sumner strait into Wrangel narrows.

186 m.
300 km. **Wrangel Narrows.**—At the entrance to the narrows the shores are composed largely of greenstones, which, however, soon give way to black slates and calcareous beds.

208 m.
335 km. **Petersburg.**—After passing Petersburg the course enters Frederick sound and approaches the mainland, where the metamorphic influence

Miles add
Kilometres

of the Coast Range batholith is clearly expressed in the sedimentary rocks (argillites and schists) outcropping along the shores. Pegmatite dikes are also more abundant near the batholith contact.

335 m.
540 km. **Juneau.**—Near Juneau the rocks exposed along the shores are greenstones alternating with black slates. Toward the east the greenstones (originally lava flows and tuffs) are less common, and the entire formation consists of black slates in different stages of metamorphism. These slates pass in turn into the highly schistose rocks of the Silver Bow basin. The planes of cleavage, and usually also of stratification, strike northwesterly and dip at high angles northeast into the mountains. Intrusive dykes of diorite and related aplitic rocks occur frequently and are intimately associated with the mineralization in this region. The Treadwell group of gold mines on Douglas island opposite Juneau are located on mineralized diorite dykes intrusive along or near the contact between black slate and greenstones bands. These dykes were much fractured after intrusion, and the fracture cracks were subsequently filled with gold-bearing quartz veinlets. The zone of mineralization here is nearly 400 feet (122 m.) in width and has been traced for over 3,500 feet (1 km.) along the strike. Much of the gold is free milling and is associated with pyrite and some pyrrhotite and magnetite and many other less abundant minerals. The Treadwell group alone has produced nearly $50,000,000 worth of gold and is one of the largest gold mines in the world.

391 m.
630 km. **Lynn Canal.**— Continuing north from Juneau the route enters Lynn canal and gradually approaches the Coast Range batholith. At 416 miles (670 km.), or abour 25 miles (40 km) above Berners bay, the east shore of Lynn canal is bordered by the batholith, which is continuously exposed to Skagway at the head of Taiya inlet and beyond to White pass and Lake Bennett in British Columbia. The elon-

Miles and
Kilometres

gated, finger-like peninsulas at the junctions of Chilkat, Chilkoot, and Taiya inlets are typical glacial junction spurs which have resulted from the action of the large valley glaciers confluent at acute angles. The glaciers overrode the junction spurs and cut them to the present elongated shapes, rounded in transverse cross section and almost cigar shaped in plan.

460 m.
740 km. **Skagway.**—At Skagway several different types of the granitic and dioritic rocks occur; the Skagway aplitic and pegmatitic rocks are specially interesting.

THE SKAGWAY—WHITEHORSE—DAWSON SECTION.

BY

D. D. CAIRNES.

GENERAL TOPOGRAPHY AND GEOLOGY.

In going northward from Skagway over the White Pass and Yukon railway, the traveller commences at once to cross the Coast range and reaches its northern or northeastern border in a distance of about 45 miles (72 km). Thence, continuing over the railway to Whitehorse and down Lewes and Yukon rivers to Dawson, 571 miles (914 km.) from Skagway, the journey is within the southwestern and central portions of the Yukon plateau, Yukon river occupying a median position in this physiographic province. The main physiographic systems of Yukon Territory, as well as those of British Columbia to the southeast and of Alaska to the west and northwest, trend in a general way parallel to the Pacific Coast line, following its peculiar curved contour.

Physiographic Provinces of Yukon by D. D. Cairnes.

The Coastal system from about the 50th to nearly the 60th parallel of north latitude embraces only the Coast range, if the islands to the west be considered to form a separate range [**29**, p. 4; **30** pp. 61, 62], but this simplicity is interrupted near the head of Lynn canal, whence northward and northwestward, the Coastal system consists of different ranges, in some cases separated by wide valleys, as well as by other subordinate mountain masses. The Coast range, after following the coast line from Southern British Columbia to nearly the head of Lynn canal, passes behind St. Elias range, and thence northward constitutes the most easterly portion of the Coastal system, becoming gradually less prominent until it merges into the Yukon plateau near Lake Kluane, at latitude 61° and longitude 138° 30′. The Coast range consists, in a general way, of an irregular series of peaks and ridges, that possess but little symmetry other than a rough alignment parallel to a northwesterly-trending axis. The range has everywhere a precipitous and jagged aspect, and consists largely of knife-edged crests, rugged or even needle-like summits, and sharply-incised valleys. The summits in the vicinity of the White Pass and Yukon railway rise to altitudes of 5,000 to 6,000 feet (1,500 to 1,800 m.) above sea-level, and on account of a certain uniformity of summit level, which bears no relation to structural features, this terrane has been considered by a number of geologists [**33**, p. 128; **66**, p. 132; **6**, pp. 286-290; **293**] who have studied it topographically, to represent a peneplanated or at least a mature to old surface of erosion, subsequently elevated. As mentioned in the Prince Rupert—Skagway section, however, the evidence on this point does not appear to be conclusive, and the uniformity of summit level may be the result of various other causes.

Bordering the Coastal system along its inland edge, and stretching thence eastward, northeastward, and northward to the Rocky Mountain system is the great Interior system of plateaus and mountains, the most northerly member of which, the Yukon plateau, has a width in Northern British Columbia and Yukon of 250 to 300 miles (400 to 480 km.). In places some well defined ranges or groups of mountains lie within this plateau province.

Into the upland surface of the Yukon plateau in Southern Yukon, the main drainage courses have incised channels varying from 3,000 to 4,000 feet (900 to 1,200 m.),

producing thereby a very irregular topography. The summits of the unreduced hills and ridges, lying between the waterways, mark a gently rolling plain which slopes toward the north and northwest. The plateau is best seen from a summit that stands at about the level of the upland, where the observer will be impressed with the even sky-line, sweeping off to the horizon and broken only here and there by isolated, residuary masses rising above the general level. This plain, however, bears no relation to rock structures, erosion having bevelled the upturned edges of the hard as well as the soft strata. The surface, consequently, is entirely discordant to the highly contorted, metamorphosed rocks that make up much of the plateau.

Along the northern portion of the Coast range, the general summit of this terrane merges into that of the Yukon plateau in a manner suggesting the synchronous planation of these two provinces,—a view that is held by Brooks [**6**, pp. 286-290, 293], Spencer [**67**, p. 132], and others. The various vertical movements that have affected these terranes, however, whether the Coast range was planated or not, have been such that the uplift has been greatest along the axis of the Coast range and least along that of the Yukon plateau, so that the latter possesses the contour of a huge flaring trough whose median line is in a general way, marked by the course of Yukon river from its headwaters in Northern British Columbia to Bering sea.

As topographic features are often to a certain degree merely expressions of the bedrock structure and composition, it might be expected that the same general geological terranes would extend through Alaska, Yukon, and British Columbia, following the general trend of the coast line, and to a limited extent this has been found to be true. In Yukon, however, this parallelism, and to some extent conformity of geological formations to the physiographic provinces, is most apparent when the entire territory is considered. The Coast range everywhere consists almost entirely of the granitic materials composing the great Coast Range batholith, and the various geological terranes of the Rocky Mountain system have a decided general trend parallel to its physiographic boundaries. In the Yukon plateau, however, the different geological formations are somewhat irregularly distributed and have no marked trend parallel to the borders of the plateau province.

As mentioned above, the rocks composing the Coast range are dominantly granitic in character, and although mainly granodiorites, they range from gabbros to granites. They were intruded at different times, commencing early in the Jurassic and extending probably up into the Cretaceous. The geological terranes of the Yukon plateau in Southern Yukon, range in age from apparently Pre-Cambrian to Recent, and include sedimentary, igneous and metamorphic members.

The succession of geologic events in that portion of Yukon plateau included in Southern Yukon and Northern British Columbia, and particularly that portion traversed in journeying from Skagway to Dawson, will now be presented in so far as they are known. The information available, however, is rather fragmentary, and for long periods the records have been almost or entirely destroyed. Still it is hoped that a brief treatment of the data obtainable will give a general idea, at least, of the various vicissitudes which the district has undergone.

The oldest records are contained in a group of rocks, partly igneous and partly sedimentary, which consist dominantly of schists, gneisses, and some impure limestones. These rocks are extensively developed in the vicinity of Dawson and elsewhere in Yukon, and have given rise to the famous placer gold deposits of the Klondike and other districts. These rocks have been generally considered to be of early Paleozoic age, but recent investigations by the writer [**20, 21**] tend to show that they are in part or entirely Pre-Cambrian in age. These rocks show that there were accumulated at an early stage in the history of the district, thousands of feet of arenaceous and argillaceous matter, followed also by great thicknesses of calcareous material, and that vulcanism was active during and after sedimentation. The relative ages of the various members are imperfectly revealed, since all are now greatly metamorphosed, plicated, distorted, and eroded and appear as a group of rocks consisting dominantly of sericite-schists, chlorite-schists, actinolite-schists, quartz-schists, mica-schists, schistose amphibolites, mashed and sheared diabases, greenstone-schists, quartzites, gneisses, and impure limestones.

Parts of Yukon Territory appear to have been inundated by the sea from early Cambrian to late Carboniferous time, during which time, calcareous sedimentation was apparently continuous. From Dawson southward, how-

ever, the records are very indistinct from the period at which the older schistose rocks were formed until late Silurian or Devonian times when a great portion of the district was involved in a widespread dynamic revolution, which caused extensive deformation and metamorphism and was accompanied by considerable volcanic activity. At the close of this disturbance a considerable area was above the sea and a long erosion interval ensued. Some time before the middle Devonian, however, a great part of Yukon sank beneath the sea, and at about that time vulcanism became active at a number of points. The older pyroxenites and andesitic members of the Perkins group are thought to have been intruded at that time.

This sea invasion prevailed at least well into the Carboniferous, and several thousand feet of calcareous, siliceous, and argillaceous sediments, now represented by quartzites, cherts, slates, and limestones, were deposited. The limestone hills, ridges and ranges, that are now so prominent along Tagish lake, Lewes river, Lake Laberge, and elsewhere, are the result of this period of deposition. Sedimentation was brought to a close by a widespread deformation, and at about this time vulcanism became active, and andesitic rocks invaded the district and buried extensive areas under flows and tufaceous accumulations.

In Jurassic—apparently early Jurassic—time an extensive crustal movement occurred which was accompanied by the injection of vast amounts of igneous materials, including the earlier of the great batholiths of the Coast range. These batholiths constitute probably the largest exposed post-Paleozoic intrusive masses in the world, and afford unexcelled opportunities for the study of batholithic intrusions on a tremendous scale.

A considerable area was above the sea at the close of this disturbance, and what was probably a short period of erosion ensued. This was followed by a gradual sinking of the land in Jura-Cretaceous time, which continued until an extensive land mass was submerged.

The materials accumulated in this Jura-Cretaceous sea were chiefly such as have produced upon consolidation, arkoses, conglomerates, sandstones, shales, and coal seams. These rocks have an aggregate thickness in places of over 6,000 feet (1,800 m.) and nowhere has the original top of the series been discovered, the uppermost beds having now been removed by erosion. All the bituminous and anthracitic coals of Yukon were deposited during this period.

This Jura-Cretaceous period was also characterized by intense volcanic activity, the evidence of which is recorded in the great amount of ash and volcanic breccia intercalated with the normal sediments and in places even exceeding them in amount. In places, dykes are numerous and flows are extensive, and everywhere the volcanics of this period appear to be andesitic in character. Vulcanism persisted until after sedimentation had ceased, and along Nordenskiöld river great masses of these andesites occur overlying eroded surfaces and edges of the Jura-Cretaceous sediments.

A widespread deformation terminated the Jura-Cretaceous period of sedimentation, at the close of which a considerable land mass, comprising the greater part of southern Yukon at least, was above the sea. Degrading action followed, and from that time to the present there is no evidence to show that any portion of the district between Skagway and Dawson has been submerged beneath the sea.

Following this Jura-Cretaceous disturbance, and mainly, it is thought, during Tertiary, but possibly extending into Pleistocene time, the district was subjected to several volcanic invasions. As a result of what appears to be the oldest of these invasions, basalts pierced the older formations and flowed over the land surface, and in places, hundreds of feet of basalt-tuffs accumulated. The basalts exposed in Miles canyon, along Lewes river below Tantalus, and along the river above and below Selkirk, all belong to this period. Along Nordenskiöld river near Carmack, the basalt-tuffs have their greatest known development. About this time, dykes of granite-porphyry, syenite-porphyry, and rhyolites invaded the older formations, and rhyolites also flowed over the land surface, generally in thin sheets, and in places were accompanied by great amounts of related tuffs and breccias. To the north and especially in the vicinity of Indian river, diabases and andesitic rocks occur intimately associated with sediments considered to be of Eocene age.

In upper Cretaceous time a transgression of the sea took place along the present Yukon basin and also probably extended to other portions of Alaska and Northern Yukon. Deposition continued well into the Eocene, although in the upper Yukon basin the Eocene is represented only by fresh water beds which seem to have been laid down in isolated basins. The Kenai lignite-bearing beds of the Rock Creek coal area, which extend along the east side of Yukon river

for 70 miles (110 km.) below Dawson, as well as all the other Tertiary areas of lignite-bearing beds belong to this period of deposition. Developments of similar sediments associated with diabases and andesitic and rhyolitic volcanics occur in the vicinity of Indian and Fortymile rivers, within a few miles of Dawson. These are the most southerly of these Tertiary sediments developed in Yukon or in the district between Dawson and Skagway.

In Eocene or Miocene time, a gradual uplift occurred which, though of an orographic character, was accompanied by volcanic activity and by a considerable local disturbance of Eocene beds. The exact date of this orogenic movement is somewhat in doubt. Dawson [**30,** p. 79] refers the uplift to the Eocene, but Brooks [**6,** pp. 292, 293] has produced considerable evidence to show that the dynamic revolution occurred during late Eocene or early Miocene time. A long period of crustal stability ensued, during which what is now the Yukon plateau as well as, in the opinion of some geologists, the Coast range and other adjoining tracts [**67,** pp. 117, 132] were reduced to a nearly featureless plain which was subsequently elevated. Dawson [**29,** pp. 11-17] maintains that the planation was accomplished during the Eocene epoch, and that the Miocene was a period of vulcanism, deposition, and accumulation, and agrees with Brooks [**6,** pp. 290, 292, 293] in considering that the subsequent uplift occurred in Pliocene or early Pleistocene time. Spurr, however, shows that the erosion of the Yukon plateau was contemporaneous with the deposition of the Miocene strata in the lower valley of Yukon river and, therefore, urges that the Yukon plateau was planated in Miocene time and subsequently uplifted in late Miocene or early Pliocene time. [**70,** pp. 260, 262, 263]. From the information available, however, it seems probable that the Jura-Cretaceous sediments were largely deformed by the Eocene or Miocene (post-Laramie) dynamic movements; that the district was peneplanated during Eocene or pre-Pliocene post-Eocene time; and that this planated tract was uplifted to practically its present position during the Pliocene epoch.

During the long period of crustal stability previous to this last important uplift the topography was reduced to the form of a broad and gently undulating plain, and only occasional unreduced hills and ridges remained projecting above the general level. This lowland surface

then became elevated, and the streams of the district were thus given renewed life and erosive powers, and consequently immediately commenced sinking their channels in the uplifted peneplain. Soon, numerous, deep incisions were carved, which intersected the region in various directions. The interstream areas became more and more individualized, and assumed gradually the aspect of separate mountains and ridges.

The uplift of the Yukon plateau and adjoining tracts was of a differential character, and so conditioned that the resultant topography had the contour of a broad shallow trough, the approximate axis of which is marked by the present position of Yukon river and its main tributary the Lewes, while the Coast range lies along its western or southwestern rim.

The higher tracts, including the ranges of the Coastal system, during the Pleistocene, became the gathering grounds for glaciers, and huge tongues of ice moved down the sides of the Coast range both seaward and inland. These valley-glaciers accentuated the topography produced by uplift and subsequent erosion, and deepened and broadened the depressions they occupied, steepened the valley walls, and sculptured the land forms in a manner characteristic of ice action. Vast amounts of morainal and other materials were carried southward to the Pacific, and northward on the way to Bering sea. The floors of the main valley bottoms of Southern Yukon are deeply covered with these deposits. Distinct ice markings occur along the valleys of Lewes and Nordenskiöld rivers nearly to Tantalus, and are claimed to have been found a few miles below this point. All traces of the presence of glacial ice vanishes, however, long before Dawson is reached.

After the retreat of the ice the topography was virtually that of to-day. The master-streams have been since engaged in removing the burden of glacial sands, gravels, clays, and silts from their valleys and have not as yet succeeded in trenching their channels to bedrock.

A thin veneer of Recent materials forms the surface nearly everywhere. This consists mainly of sands, gravels, clays, and silts of the present waterways, ground-ice, muck, volcanic ash and soil. The volcanic ash is an interesting feature and occurs as a layer of pumiceous sand ranging in thickness from less than an inch (25 mm.) to over 2 feet (·6 m.) This material is noticed as far south as Lake Bennett, where near Caribou it is about an inch

(25 mm.) thick, but it increases in thickness to the north and west for over 200 miles (320 km.). It is calculated that this covers about 25,000 sq. miles (64,800 sq. km.) and has a volume of at least a cubic mile. (4 cu. km.). It is remarkably homogeneous and of more recent age than the silts which are the latest of the glacial deposits. In fact, this ash has fallen since the present waterways have cut their courses to approximately their present depths, and the trees and vegetation are rooted in it. On account of its even distribution, it appears to have fallen very tranquilly and continuously, since in it, as originally deposited, no intercalated layers of foreign materials exist. Mt. Wrangel is the nearest known volcano that is at present active, and as the ash appears to increase in that direction, this or some yet undiscovered volcano in that vicinity is probably the source of the material.

CLIMATE, FAUNA AND FLORA.

As no description of Yukon would seem at all complete without some mention of climate, flora and fauna, these will now be very briefly considered [**45**]. The climate and vegetation of the southern slope of the Coast range north of Skagway, are similiar to those of other parts of Southeastern Alaska, and have been described in other sections of this guide-book, so will not be further mentioned here.

The climate of Yukon has been, and by many people still is greatly misunderstood. In fact until recently this territory has been popularly believed to be a region extremely difficult of access, and covered by almost perpetual snow and ice. Winter photographs, sensational newspaper descriptions of the Chilcoot pass and the building of the White Pass and Yukon railway, and stories, generally exaggerated, of the privations suffered by those who joined in the early rush to the Klondike are mainly responsible for these opinions.

Now, since the building of the railway over the White Pass summit, and since lines of steamers have been placed on some of the lakes as well as on Yukon river and its main tributaries, the district has come to be better and more favourably known.

The climate of Southern Yukon (south of Dawson) is, during the summer, particularly delightful. On account

of the northern latitude, there is almost continuous daylight during June and July; and for five months, typical warm summer weather prevails. The amount of rain varies greatly in different localities according to elevation and proximity to mountain ranges.

The rivers generally open early in May, but the ice remains on some of the lakes until the first week in June. Slack water stretches freeze over at any time after the middle of October, but during some seasons, the rivers remain open until well into November.

The climate is in a general way similar to that in many parts of British Columbia and other northerly mining camps in the world and few more difficulties have to be met there, in actual mining operations, than in localities farther south. At least six months in each year are suitable for surface working and for the necessary outside operations contingent to mining. Further, during part of the summer, outside work can be continued by night as well almost as by day without the aid of artificial light. The ground is in most places permanently frozen to varying depths, but this does not interfere with mining operations, except while such are being conducted at or near the surface, and in underground placer mining the frost is often an advantage, as when the ground is frozen timbering is not necessary.

The forests of Southern Yukon are nowhere as heavy or dense as those of more southerly latitudes, still in most of the valleys and on many of the slopes up to an elevation of 3,000 to 4,000 feet (900 to 1,200 m.) above sea-level, there is a fair growth of useful timber. On the hillsides the trees become dwarfed near timber line and there give place to shrubbery. The higher elevations are moss-covered or bare.

The forest consists chiefly of 12 or 13 species, 8 of which attain the dimensions of trees. These are the white spruce, *Picea alba*, black spruce, *Picea nigra*, balsam fir, *Abies subalpina*, black pine, *Pinus Murrayana*, balsam poplar, *Populus balsamifera*, W. balsam poplar, *Populus trichocarpa*, aspen poplar, *Populus tremuloides*, and white birch, *Betula alaskana*.

Several varieties of wild fruits grow very abundantly, and many of the wide, flat, extensive valleys are covered with luxuriant growths of wild grasses. Also many varieties of vegetables grown at Dawson, Whitehorse and intermediate points compare favourably with those imported. Moreover, it is well known that horses winter safely in

A sled load of lake trout caught at Tatalamana lake, 30 miles east of Minto on the W. P. and Y. railway.

many of the valleys without being fed. In fact extensive portions of Yukon are considered to be very suitable for stock-raising and agricultural purposes. The great abundance of beautiful flowers in the gardens at Dawson are always a source of wonder to those unfamiliar with the district.

Moose, caribou, sheep, and black, brown, and grizzly bears are plentiful in many districts, as well as many varieties of valuable fur-bearing animals. The streams and lakes nearly everywhere abound in fish, chiefly, grayling, whitefish, lake-trout, pike and salmon.

ANNOTATED GUIDE.

0 m.
0 km. **Skagway**—Altitude 0. ft. Leaving Skagway the train begins almost immediately a steady climb over the mountains of the Coast range, and in most places the granitic rocks of the Coast range batholith are well exposed. The railway zigzags up the precipitous mountain sides, passing the hanging rocks at Clifton, and rounding one point after another where huge masses of rock have been blasted away. Looking down hundreds of feet below the track, in places, can be seen the foaming, rushing Skagway river, and the old trail over which so many men struggled in their mad rush to the Klondike before the building of the railway. Still ascending, the train passes through the tunnel, thence over the steel cantilever bridge 215 feet (65 m.) above the bottom of the canyon. Everywhere the smoothed, polished, naked rock surfaces, the precipitous-sided U-shaped valleys of the larger streams and the hanging valleys of their tributaries are evidence of intense glaciation. The scenery here is wild and rugged in the extreme.

*19.7 m.
31.5 km. **White Pass**—Altitude 2,887 ft. (878 m.) The White Pass summit of the Coast range is on the boundary between United States and Canadian territory and the train here passes from

*The distances and elevations between Skagway and Whitehorse have been kindly furnished by the International Boundary Survey department, Ottawa, and the figures are the results of observations made by Mr. Douglas Nelles, D.L.S., 1908-1910.

Skagway, Alaska.

Alaska into British Columbia. The character of the scenery changes rapidly to the north of the summit, becoming less rugged as the Yukon Plateau is approached. Leaving the summit the train runs along various small lakes and streams to Lake Bennett.

39.7 m.
63.5 km. **Bennett**—Altitude 2,158 ft. (656 m.). At Bennett near the head of Lake Bennett, a stop is usually made for luncheon. Continuing, the train runs along the shores of the lake for 27 miles (43 km.), the scenery being particularly beautiful. About 31 miles (50 km.) from the summit, the 60th parallel of latitude is crossed, which is the boundary between the provinces of British Columbia and Yukon Territory. The typical Coast Range intrusives continue along the railway to a point about 11 miles (17 km.) from Caribou, thence for 6 miles (9.6 km.) porphyrites, andesites, basalts, tuffs, and tufaceous sandstones and shales of Jura-Cretaceous age outcrop along the railway. Thence for about a mile, quartzites, slates, and limestones, thought to be of Devonian age, are developed. Typical granodiorites continue to Caribou.

Lake Bennett and other similar bodies of water forming the headwaters of Yukon river, are of particular interest, and various theories have been advanced to account for their origin. It appears, however, that these lakes represent the positions occupied by the last great tongues of the retreating valley glaciers, and that the ice melted so rapidly toward the last that the depressions it occupied had not time to become filled with glacial débris as did other valleys and other portions of these valleys.

The valley of Lake Bennett, which is really a southern continuation of the broad depression extending northward from Caribou toward Whitehorse, is typically U-shaped, has high precipitous walls rising abruptly from the water's edge in places, and, particularly along the western side of the lake, has had all projecting points and spurs planed away by northward moving valley glaciers. Virtually all the

Caribou (Post Office name is Carcross), on the White Pass and Yukon railway.

tributary streams entering this valley have hanging valleys, and in general the effects of valley glaciation are here so pronounced as to make it an ideal region in which to study these phenomena. [**17**, p.p. 11--23].

The terraces seen along Lake Bennett at various elevations possess considerable interest, particularly as similar terraces characterize almost all the main valleys not only in Central Yukon but in adjoining portions of British Columbia and Alaska. They are well developed along Lewes river below Whitehorse, along Lake Laberge, along Nordenskiöld river, and elsewhere. A number of theories have been advanced at different times to explain the origin of these terraces, but the majority of such explanations fail when all the known facts and the extent of the region throughout which the terraces occur, are considered. The writer has investigated these in different districts in the Yukon [**17**, pp. 21-23.] and Northern British Columbia [**18**, see section on "Terraces"] and believes them to be all lake terraces formed in post-Glacial times, owing their origin to a temporary damming of Yukon river near its mouth, possibly by ice, and a consequent brief flooding of the entire river system.

66·7 m. **Caribou**—Altitude 2,171 ft. (660 m.) At
106·7 km. Caribou the train crosses, on a swing bridge, a narrow stream of water connecting Lake Bennett and Nares lake. Thence for over 30 miles (48 km.) the railway follows a wide northerly-trending depression, the floor of which is deeply covered with glacial accumulations which are in places hundreds of feet in thickness. Everywhere the valley bottom is characterized by kettle holes and morainal deposits, and has the general appearance of still being almost as the ice left it. About 15 miles (24 km.) north of Caribou, a lake which was originally about 3 miles (4·8 km.) long was partly drained during the construction of the railway, and there splendid sections of the silts, in places exceed-

Shooting Miles canyon.

ing 100 feet (30 m.) in thickness, are to be seen. To the west of the railway, and in most places within a distance of half a mile, Watson river follows an exceedingly tortuous course from near Robinson to Lake Bennett, a distance, as the crow flies, of about 18 miles (29 km.) For this portion of its course, the river is in most places a slow, deep, sluggish stream.

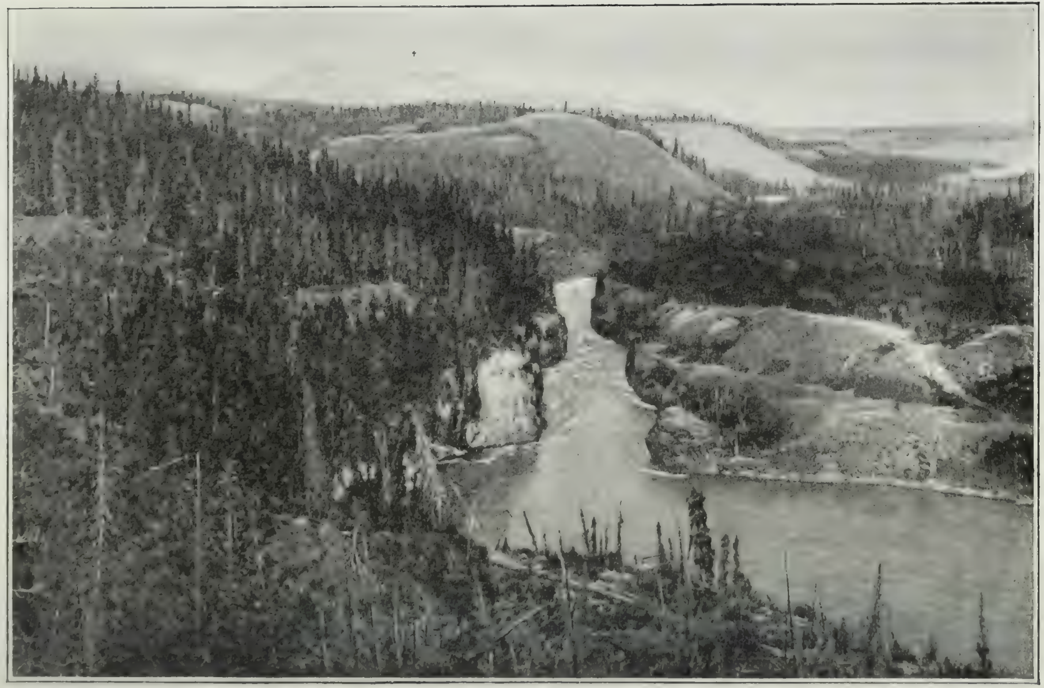
Practically the only consolidated rocks that outcrop at all close to the track along this part of the journey constitute a low sharp ridge running along the west side of the railway 5 or 6 miles (8 to 10 km.) north of Caribou. These rocks are dominantly Jura-Cretaceous conglomerates and sandstones, and in places are decidedly reddish on weathered surfaces.

About 10 miles (16 km.) before reaching Whitehorse, Lewes river comes into view, having broken its way through the high mountain ridge running parallel to the railway on the east. Five miles (8 km.) farther on, the railway swings close to the river at a point near the head of Miles caynon, and from there a splendid view is afforded of the canyon with its walls of Tertiary basalt showing pronounced vertical columnar jointing.

During Pleistocene time, the former channel of Lewes river became filled with glacial débris, causing the stream to become diverted from its former course. After the retreat of the ice, the river had become superimposed on the basalts in the valley and, in rapidly sinking its channel to obtain grade, produced the famous Miles canyon. In shooting this canyon and the Whitehorse rapids below, many men have lost their lives, particularly during the early days of the Klondike excitement and before the construction of the railway.

From the head of the canyon, the railway descends with a steep grade to the town of Whitehorse which is situated at the head of
110 m. navigation on Lewes river, the main tributary
176 km. of the Yukon.

Whitehorse—Altitude 2,083 ft. (633 m.)



Miles canyon, as seen from the White Pass and Yukon railway.

WHITEHORSE COPPER BELT.*

General Description.

The Whitehorse copper belt is situated in the southern part of Yukon Territory, about 45 miles (72 km.) north of the British Columbia boundary, and extends along the western side of the valley of Lewes river—the principal feeder of the Yukon—for a distance of about 12 miles (19·2 km.) Most of the important mining properties are situated at distances of from 4 to 7 miles (6·4 to 11·2 km.) from the present terminus of the White Pass and Yukon railway at Whitehorse.

The oldest rocks known in the district are limestones referred to the Carboniferous. These have been extensively invaded by Mesozoic andesites and also by plutonic rocks ranging in composition from typical hornblende granites to gabbros. The youngest consolidated rocks in the district are basalts of Tertiary age. All are overlain by Pleistocene and Recent deposits. The ore-deposits are of contact-metamorphic origin and occur dominantly in the limestones near their contact with the granitic rocks; they are also developed in places in the granitic intrusives.

Particular Description.

Topographically, the main feature of the district, is the great valley of Lewes river. Opposite Whitehorse the valley has a width from base to base of the enclosing hills, of fully 4 miles (6·4 km.) It is bordered on the east by Canyon mountain, a long symmetrical limestone ridge rising to a height of 2,500 feet (760 m.) above the valley bottom, and 4,730 feet (1,438 m.) above the sea. The western boundary is more broken, and consists, from south to north, of Golden Horn, a prominent peak 5,400 feet (1,542 m.) in height; a wide irregular ridge culminating in Mount McIntyre, 5,200 feet (1,581 m.); and Mount Haeckel, 5,318 feet (1,617 m.) in height. These elevations are separated by wide drift-filled depressions, extending across the range.

*The descriptions here given of the Whitehorse Copper belt are mainly summarized from Mr. McConnell's report on the district [**59**], supplemented by recent observations by the writer.

Whitehorse, the northern terminus of the White Pass and Yukon railway.

The central portion of the old pre-glacial valley is floored with silts and boulder clays, and through these the Lewes has cut the narrow, winding, secondary valley, about 200 feet (61 m.) in width, in which it now flows.

The oldest rocks known in the district are limestones, which are referred to the Carboniferous. These have been broken through and largely destroyed by three distinct igneous invasions. The earliest invasion was by andesites of various kinds. These were intruded, partly at least, in the form of sheets or sills up to 1,000 feet (304 m.) or more in thickness. The second invasion is represented by plutonic rocks, which range in mineralogical composition from hornblende granites to augite syenites, diorites, and even to gabbros. These rocks cover a large portion of the district and may represent an outlier of the Coast Range batholith. The third period of igneous activity resulted in the production of the numerous porphyrite dikes now found cutting indiscriminately across limestones, granites, and older andesites. These dikes occur throughout the district, and in certain areas cover approximately half the surface. The youngest consolidated rocks in the district are basalts. These originated outside this belt and entered it through a depression north of Golden Horn. They flowed down the valley of Hoodoo creek to Lewes river, and continued down the river valley to Whitehorse rapids. The basalts were followed by the deposits of the glacial period, consisting mainly of boulder clays and silts, vast quantities of which floor the old valley of Lewes river in the vicinity of Whitehorse. Recent superficial deposits constitute a thin covering overlying the older formations in most places.

The copper belt, as determined by recent discoveries, extends along the valley of Lewes river, from a point east of Dugdale on the White Pass and Yukon railway, northwestward to the base of Mount Haeckel, a distance of about 12 miles (19·2 km.) The width of the belt seldom exceeds a mile (1·6 km.), and in places is confined to a single line. The distribution of the discoveries along the belt is exceedingly irregular. The ore deposits are considered to be of contact-metamorphic origin, and their outcrops dominantly follow a series of limestone areas enclosed in granite, but in places occur between granite and andesite. Where the limestone is absent the belt is practically barren; and considerable stretches of it

otherwise favourable, are deeply buried beneath heavy accumulations of drift.

The principal ore bodies, now being developed, occur in limestone, close to or adjoining the granite. Numerous discoveries have also been made in the granite, often at considerable distances from the limestones. The limited amount of work done on these has so far, however, not disclosed ore bodies of commercial value. The constituent minerals and general character of the ore bodies in the two formations, are very similar. Copper minerals seldom occur in the andesites, but are not altogether unknown there.

The principal economic minerals of the district are bornite and chalcopyrite. Tetrahedrite, chalcocite, malachite, azurite, cuprite, malaconite, chrysocolla, and native copper also occur. The oxides are conspicuous in all the workings, but except at the Pueblo, are seldom important as ores. The iron sulphides are not abundant and nowhere form large masses. The iron oxides, magnetite and hematite, on the other hand are widely distributed, and both occur in large masses. Other metallic minerals of less frequent occurrence are arsenopyrite, stibnite, galena, sphalerite, and molybdenite. Gold and silver occur in all the ores, the values ranging from traces up to several dollars per ton. Gold is ocasionally found native. The principal non-metallic minerals accompanying the ores are andradite, augite, tremolite, actinolite, epidote, calcite, clinochlore, serpentine, and quartz. Of these, andradite, augite, calcite and tremolite are the most abundant. Quartz is sparingly distributed and seldom occurs in quantity.

The ore bodies fall into two classes:—those in which the copper minerals are associated with magnetite and hematite; and those in which the various silicates, principally garnet, augite, and tremolite are the chief gangue minerals.

The magnetite ore bodies are numerous, and occur enclosed completely in altered limestone, along the lime-granite contact, and in a few instances in areas of altered granite. The largest bodies, so far discovered, are: the Best Chance, 360 feet (109 m.) in length; the Arctic Chief, 230 feet (70 m.); and the Little Chief, 100 feet (30 m.) The magnetite masses are always sprinkled, more or less plentifully throughout, with grains and small masses of bornite and chalcopyrite. The copper percentage varies

greatly in different parts of the same deposit, the general average approximating 4 per cent. The gold and silver are negligible in some of the ore bodies and important in others. Besides the copper minerals, serpentine, calcite, clinochlore, and other secondary minerals, as well, rarely, as pyrrhotite and sphalerite, occur associated with the magnetite.

Hematite masses are much less common than those of magnetite. The Pueblo deposit is the only large body known, and is over 300 feet (91 m.) long and 170 feet (52 m.) wide near the centre. This differs from the magnetite ore bodies principally in the greater oxidation of the copper minerals. Some chalcopyrite survives in portions of the deposit, but no bornite in known to have been found.

Deposits characterized by a garnet-augite-tremolite gangue are numerous wherever the lime-granite contact is exposed. They vary from low grade deposits containing only a sprinkling of copper minerals to considerable lenses of shipping ore, such as those developed on the Grafter, Copper King, War Eagle, and Valerie. All the important ore bodies of this class, so far discovered, occur in the limestone close to the granite, and are often separated from the granite by a zone of more or less completely replaced limestone. The valuable minerals are similar to those in the iron masses, and consist mainly of bornite and chalcopyrite. At the Valerie, bornite is absent, and the chalcopyrite is associated with mispickel, the only known occurrence of this mineral in the camp. The siliceous ores contain, as a rule, a higher copper percentage than the iron ores: those shipped up to the present time probably average over 8 per cent. The precious metal contents are moderate, seldom exceeding $3 per ton (·907 tonne).

The development work on the different properties has been practically all performed at or near the surface, little work having been performed at a depth exceeding 100 feet (30m.) With the exception of the Pueblo, the development work other than surface cuts, pits, etc., has been performed by ordinary shafts, tunnels, drifts, etc. On the Pueblo, two shafts have been sunk, but the bulk of the ore has been obtained from the surface by the open-cut or "glory-hole" method, much resembling quarrying. During the summer of 1912, previous to September 1st, over 22,000 tons (19,958 tonnes) of ore had been

mined and shipped from the Pueblo, and it was expected that double this amount would be mined before the winter. During 1912, the Pueblo, Grafter, Best Chance, and Valerie, were being worked most of the summer. About 150 men were employed, of whom 100 to 120 worked at the Pueblo. It is expected that the various properties of the district will be worked somewhat more extensively during the summer of 1913 than in 1912.

During the summer of 1907, Mr. McConnell estimated that probably half a million tons (454,000 tonnes) of ore was in sight, as a result of the development work then performed. [**59**, p. 3]

Historical.

The history of the Whitehorse copper belt dates back to the early Klondike rush. Discoveries of copper are reported to have been made by miners on their way to Dawson in the summer of 1897. The credit of staking the first claim is due to Jack McIntyre who located the Copper King, July 6, 1898. A number of other claims were located soon after during the same year. In 1900, the first shipment of ore was made from the district, and consisted of 9 tons (8·1 tonnes) of rich bornite ore from the Copper King. This is stated to have yielded 46·40 per cent copper. A second shipment of 460 tons (417 tonnes) of high grade ore was made in 1903. The rising price of copper in 1906 revived interest in the camp, and a number of the most promising claims were sold or bonded. The slow progress in this camp is somewhat remarkable considering the number of favourable showings it contains, and is possibly largely due to the delay in providing proper transportation facilities.

A spur from the main line of the White Pass and Yukon railway, connecting closely with the principal mining properties, has been recently completed. This should assist greatly in the future development of the camp.

ANNOTATED GUIDE—Continued.

110 m. 176 km. **Whitehorse**—Altitude 2,084 ft. (636 m.). —From Whitehorse to Lake Laberge, a distance of about 25 miles (40 km.), Lewes river flows in a general northerly direction through a wide prominent valley. For the first 15 miles

(24 km.) below Whitehorse, the stream has an average current of about 4 miles (6·4 km.) per hour. Below this to the lake, the water is rather slack, and the bed and banks of the river are chiefly clay and sand. Throughout this distance the valley is bordered on the east by a prominent range of white bare hills of Devono-Carboniferous limestone.

123 m.
196 km.

Takhini River—About 13 miles (21 km.) below Whitehorse rapids, the Lewes is joined by Takhini river on its left limit. This stream at average low water in summer has a discharge of about 3,600 cubic feet (102 cu. metres) per second or about one-half that of the Lewes above the confluence.

136 m.
218 km.

Head of Lake Laberge—Altitude 2,050 ft. (623m.)—The valley of the Lewes at the head of the lake is occupied by low swampy flats and terraces composed, where cut by the river, of fine, in places iron-stained, post-glacial, stratified sands, overlying glacial silts.

Lake Laberge [**13,** p. 15] is irregular in outline, has a north-northwesterly trend, and is 31 miles (50 km.) long and about 2 to 5 miles (3 to 8 km.) wide. This body of water is really only a stretch of Lewes river which has become expanded as a result of damming, and possesses consequently almost no perceptible current. Conspicuous, white, Devono-Carboniferous limestone mountains extend along the eastern side of the lake, and attain elevations of about 2,000 feet (600 m.) above the water at a distance of 2 or 3 miles (3 to 5 km.) from the shore. Toward the lower end of the lake, the limestone hills rise more abruptly from the water's edge, but are there only from 400 to 1,200 feet (120 to 360 m.) high. On the west Lake Laberge is bordered by gently sloping hills which attain heights of 2,000 feet (300 m.) above the lake some miles inland and are nearly all wooded, presenting quite a contrast to the white treeless hills facing them on the east. The rocks on Richthofen island and all along the western

side of the lake, belong to the Laberge Jura-Cretaceous series, and consist dominantly of conglomerates, sandstones, shales, graywackes, and tuffs. [**13,** pp. 30-35. Also see included map of "Braeburn-Kynocks Coal Area"].

Terraces are quite conspicuous along the lake in places, and occur at various elevations up to 350 feet (100 m.) above the water. These are similar to the terraces noted along Lake Bennett and at other points south of Whitehorse, and have had a similar origin. Corresponding terraces may be seen in many places along Lewes and Yukon rivers between Lake Laberge and Dawson.

The valley walls on both sides of Lake Laberge to near the level of the general upland show evidence of pronounced glacial activity, the rock surfaces in many places, particularly along the eastern side of the lake being so smoothed, polished, and striated that it is difficult to walk over them.

170 m.
272 km.

Lower Laberge—A broad prominent depression, the Ogilvie valley, joins Lake Laberge at its extreme northwestern corner, and is evidently the valley through which Lewes river flowed in pre-Pleistocene time. During the glacial period it became so filled with gravels, sands, silts, etc., that after the retreat of the ice the river was forced to find a new outlet. The river at the lower end of the lake now turns to the northeast and breaks through an opening in the hills on that side, and to Hootalinkwa, at the mouth of Teslin river, does not follow any marked valley, but flows through a confined depression among irregular lumpy hills, seldom over 1,000 feet (300 m.) above the river. This stretch of river, which is about 30 miles along (48 km.) and is locally known as Thirtymile river, has a general trend somewhat east of north, is very tortuous, and is characterized by its swift, beautifully clear water,—the lake above acting as a huge settling tank from which the water emerges

almost free from sediment. Thirtymile river has an average current of about 6 miles (9·6 km.) per hour.

The white limestone hills are also conspicuous along this stretch of the river; the other exposed rocks are dominantly sedimentary and basic volcanics of Mesozoic age.

101 m. 322 km. **Hootalinkwa**—Government telegraph operators are stationed at both lower Laberge and Hootalinkwa. The latter is a distributing point for the Livingstone creek placer fields [**52**, pp. 25A-30A: **9**, p. 14] and other points reached by Teslin river.

The valley of the Lewes just above the mouth of the Teslin is more constricted than in most places, which is somewhat remarkable being at the point of confluence of such large rivers. The valley of the Teslin appears to be the upward continuation of the valley of the combined streams below their junction. [**13**, pp. 15-17].

From Hootalinkwa to Big Salmon, the Lewes trends in a general way almost due north and has an average current of about 4·8 miles (7·6 km.) per hour. The hills bordering the valley near Hootalinkwa rise to 1,000 or 1,500 feet (300 and 450 m.) above the river, but gradually decrease in a few miles to 800 or 900 feet (240 to 270 m.), at which elevation they continue to near Semenof hills, through which both river and valley are exceptionally constricted. This range, which is dissected by the Lewes some 5 miles (8 km.) above Big Salmon, is about 5 miles (8 km.) wide, has a general northwesterly trend and consists of rounded, wooded hills rising to heights from 1,500 to 2,000 feet (450 to 600 m.) above the river.

About 15 miles (24 km.) down the river from Hootalinkwa, thick-bedded cherty conglomerates outcrop along the left limit of the river and extend downstream for over 10 miles (16 km.) These rocks belong to the Tantalus conglomerates, an upper, coal-bearing, division

of the Jura-Cretaceous rocks of Yukon. No coal has as yet been discovered in these beds between Hootalinkwa and Big Salmon, possibly because they have not been prospected, as everywhere in Yukon where a complete section of these rocks is known to occur, valuable coal seams have been found in them. In fact the best coals so far found in Yukon occur in these conglomerates. The Jura-Cretaceous rocks and the coals in them are described later under "Tantalus Coal Mine."

On the right limit of the river opposite these conglomerates below Hootalinkwa, the rocks are volcanics, dominantly of andesitic types. The Semenof hills appear to be mainly composed of somewhat basic volcanics probably of Jurassic or Cretaceous age.

236 m.
378 km.

Big Salmon River—Below Big Salmon river the Lewes turns to the west, almost at right angles to its previous course, and flows in a northwesterly direction to Tantalus. Between Big Salmon to Little Salmon river, the valley is for 8 or 10 miles (13 or 16 km.) more than usually constricted, but just below Little Salmon, the Lewes comes into a wide basin extending several miles from the river on its left limit. Both Big Salmon and Little Salmon rivers, for several miles from the Lewes, occupy broad flat depressions. Splendid exposures and sections of silts occur along this portion of the river. The rock exposures between Big Salmon and Little Salmon consist dominantly of Mesozoic andesites, basalts and related rock types—tufaceous members being prominent at some points.

271 m.
434 km.

Little Salmon River—An Indian village and trader's post is stationed at the mouth of Little Salmon river, which possess considerable interest for strangers in this district. Steamers frequently stop here to take on wood for fuel, allowing passengers a half hour or so to go ashore.

From Little Salmon river to Tantalus, the Lewes is extremely tortuous and has an average current of about 4 miles (6·4 km.) per hour. The hills on the right bank of the Lewes in the vicinity of Little Salmon are open, high, and bare, and attain heights from 1,000 to 1,500 feet (300 to 450 m.) above the river in the vicinity. Terraces occur along considerable stretches of the river, at various elevations up to 200 feet (60 m.) above the water.

The rocks outcropping along the right limit of the river below Little Salmon to Eagles Nest, 9 miles (14 km.) distant, are all Jura-Cretaceous sediments of the Laberge series and consist dominantly of conglomerates, sandstones, graywackes, and shales. At Eagles Nest, is a small but conspicuous hill of light coloured Devono-Carboniferous limestone, which can be distinctly seen underlying the Laberge beds. From Eagles Nest to Tantalus the Jura-Cretaceous rocks are exposed continuously along the right limit of the river, and as the dips are low and the strike of the beds about parallel with the general trend of the river for a considerable distance, the same conspicuous reddish sandstones and conglomerates extend along the river for several miles at about the same elevation above the water.

The limestone beds at Eagles Nest extend across the river and are extensively developed to the south. On the left limit of the river below Eagles Nest a somewhat prominent ridge trends in a northwesterly direction and reaches the river about 17 miles (27 km.) below Little Salmon. The rocks composing the ridge are dominantly basic volcanics, and closely resemble those of the Semenof ridge near the river. From below the point where these beds outcrop on the river to Tantalus, the rock exposures are all Jura-Cretaceous sediments.

In pre-Pleistocene time, Lewes river as above mentioned, instead of following the course of the present Thirtymile river below Lake Laberge, swung to the west through Ogilvie valley and continued northward through a broad

depression at present occupied by a chain of lakes, joining its present valley again in the flat across the river from and a short distance below Eagles Nest.

314 m.
502 km.
Tantalus Butte—is situated on the right limit of the Lewes about 2 miles (3·2 km.) above Tantalus. Several seams of good coal have been discovered on this hill, three of which are 8 feet 10 in. (2·6 m.); 9 feet 10 in. (2·9 m.); and 7 feet (2·1 m.) thick respectively. These seams have not been developed other than by a limited amount of surface prospect work including a few trenches, open-cuts, etc. [**13,** pp. 52-53; **19**.]

Average outcrop samples of the 8 feet 10 in.; the 9 feet 10 in.; and the best 6 feet of the 7 feet seam, numbered respectively A, B, and C, were assayed by the Mines Branch, Department of Mines, Ottawa, and gave the following results:—

316 m.
505 km.
Tantalus Coal Mine—Altitude 1,718 feet (522 m.)

	A.	B.	C.
Water	13·64	16·32	12·87
Volatile combustible matter	31·83	31·72	31·72
Fixed carbon	51·84	42·13	49 51
Ash	2·69	9·83	5·90
	100·00	100·00	100·00
Ratio of volatile combustible matter to fixed carbon	1·63	1·33	1·56
Potash reaction	Dark.	Brownish.	Red.
Colour of ash	Pale reddish brown	Pale brownish yellow.	Yellowish brown.
Kind of fuel	Lignite.	Lignite.	Lignite.

TANTALUS COAL MINE.

General Description.

The Jura-Cretaceous beds in Tantalus Coal Area [**13,** pp. 51-53; **19; 61,** Vol. I, p. 117-118] have an aggregate thickness of about 4,800 feet (1,460 m.) and, mainly for economic reasons, have been divided into the Laberge series and the Tantalus conglomerates. [**13,** pp. 30-38, also see included map of "Tantalus Coal Area"]. The Laberge series consists mainly of conglomerates, sandstones, graywackes, and shales. The overlying Tantalus conglomerates have a maximum observed thickness in the district of about 1,000 feet (300 m.) and consist dominantly of thickly-bedded cherty conglomerates.

All the best coals of Yukon occur in these Jura-Cretaceous rocks, and are found at two distinct horizons, the upper horizon being in and near the top of the Tantalus conglomerates, and the lower horizon being in the Laberge series and within 200 to 300 feet (60 to 90 m.) of the overlying Tantalus conglomerates. The coals are dominantly bituminous in character, and some seams yield a fair grade of coke. In different portions of Yukon the Jura-Cretaceous coals range from high grade lignites to anthracites. The best and most valuable seams have so far been found in the upper horizon, to which belong those at Tantalus mine and on Tantalus butte.

Particular Description.

Tantalus mine is owned by the Five Fingers Coal Company of St. Paul, Minnesota, and is situated on the left limit of Lewes river about 205 miles (328 km.) down the river from Whitehorse.

The coal outcrops in the river banks and is, therefore, well situated for economical working. The cars are hauled out of level entries by mules, and by means of a cable, operated by a small stationary steam engine, are pulled up an incline, at the top of which the coal is dumped into bunkers ready for loading on river boats or scows. Three seams have been opened up, only the lower two of which have been worked to any extent. The seams vary somewhat in thickness, but average about 7 feet 6 in., 6 feet 6 in., and 3 feet of coal in the bottom, middle, and top seams respectively. The lower two seams have, in places,

not more than 4 feet of rock between them, and the middle and top seams are generally about 7 feet apart. The coal is worked by the pillar-and-stall system, from two level entries, which have been driven about 2,000 feet. The beds in the mine workings, dip to the east at angles ranging from 24° to 40°.

A 500 pound sample from each of these seams taken by the writer in 1908 was treated and analysed by the Mines Branch,—the following being part of the results of this work.*

	Upper Seam.		Middle Seam.		Lower Seam .	
	Raw.	Washed.	Raw.	Washed.	Raw.	Washed.
	%	%	%	%	%	%
Moisture in sample as received in laboratory....	0·9	......	0·7	......	0·7	......
Proximate analysis of coal dried at 105°C.—						
Fixed carbon..........	58·0	59·9	54·1	60·3	56·0	59·2
Volatile matter........	25·0	26·3	26·7	25·7	27·8	28·1
Ash..................	17·0	13·8	19·2	14·0	16·2	12·7
Ultimate analysis of dried coal—						
Carbon...............	6·98	......	......	......	71·1	......
Hydrogen.............	4·0	......	......	......	4·3	......
Sulphur...............	0·5	0·5	0·5	0·4	0·5	0·5
Nitrogen..............	0·8	0·8	0·9	0·8	0·7	0·8
Oxygen...............	7·9	......	......	......	7·2	......
Ash..................	17·0	......	......	......	16·2	......
Calorific value of dried coal in calories per gramme	6,700	7,110	6,310	7,070	6,790	7,210

The number of tons of coal produced from this property during the past few years is approximately as follows:—

Year—	1906.	1907.	1908.	1909.	1910.	1911.	1912.
Tons—	5,170	8,500	4,500	3,500	3,000	3,500	3,000

*For the complete results of the tests made of these fuels see the following reports:—
13, Appendix III, pp. 59-63.
61, Vol. I, Table XLIV, Vol. II, Table LXX.

ANNOTATED GUIDE (Continued).

316 m.
505 km.

Tantalus Coal Mine—Altitude 1,718 feet (522 m.) About two-thirds of a mile (1 km.) below Tantalus mine, and on the same side of the river, is a general store and a dismantled R.N.W.M. Police barracks. One-third of a mile (·5 km.) farther along the river bank is situated Carmack's road house which is on the Whitehorse-Dawson waggon-road, 131 miles (210 km.) from Whitehorse, measured along the road. About one-third of a mile (5 km.) below Carmack, Nordenskiöld river joins the Lewes on its left limit.

Lewes river below Tantalus and particularly to Five Fingers rapids, continues to be extremely tortuous, and 6 miles (9·6 km.) below Tantalus swings to the foot of Tantalus butte within half a mile (·8 km.) of a point where it had touched the base of this hill, 8 miles (12·0 km.) farther upstream. The higher hills in this vicinity rise to elevations between 3,000 and 3,500 feet (900 to 1,000 m.) above sea-level.

From Tantalus to Five Fingers coal mine, a distance by river of 16 miles (26 km.) or 8 miles (13 km.) as the crow flies, the rocks along the left limit of the river are mainly Tertiary basalts, similar to those at Miles canyon, in the vicinity of Selkirk, and elsewhere in Yukon. On the right limit of the river these rocks are also extensively developed, but the Jura-Cretaceous rocks are also exposed for about 4 miles (6 km.) above Five Fingers mine. The layer of light grey or nearly white volcanic ash, which is noticeable from Caribou northward, is particularly prominent between Tantalus and Five Fingers, where it is about a foot (·3 m.) thick, and as elsewhere is very near the surface, the vegetation being rooted in it.

332 m.
531 km.

Five Fingers Coal Mine—The Five Fingers mine [**13**, pp. 53-55; **19**] is situated on the right bank of the Lewes, and the workings are all close to the water's edge. The coal measures on this property belong to the lower

of the two main coal horizons of Jura - Cretaceous age, i.e. they occur near the top of the Laberge series and are consequently several hundred feet below the measures at Tantalus and Tantalus butte.

Some years ago, a slope was sunk about 350 feet (106 m.) on the best seam so far found in these measures, and a number of rooms were driven off this entry. The seam dips to the east at an angle of 16°, and in the lower rooms, is 3½ to 4 feet (1·0 to 1·2 m.) thick. A considerable amount of coal was mined and sold, chiefly in Dawson, but the workings have now been closed for several years.

The top of this old slope is situated in the steep clay and sand bank of the river, and is therefore unstable; consequently when work was resumed under new management in 1906, the entrance was shifted to safer ground, some distance to the south. The new slope was sunk 783 feet, (238 m.) on a seam which also dips at 16° to the east, and is higher in the measures than the seam in the old workings. This upper seam, through in places not more than 6 inches (·15 m.) thick, shows at the bottom of the slope 22 inches (·55 m.) of good clean coal, and 24 inches (·6 m.) of coal and shale.

During 1907 and 1908, very little work was done on the property. In the former year a 26 ft. (7·9 m.) winze was sunk at a point 450 feet (136 m.) down the new slope, to a coal seam 4 ft. 6 in. (1·3 m.) thick, which is apparently the same seam as that in the old workings. Since 1908 the mine has been closed .

The following samples were taken by the writer:—Sample A is an average of the 22 inches (·55 m.) of good coal in the bottom of the 783 ft. (238 m.) slope; and B an average of the bottom of the 26 ft. (7·9 m.) winze. Assayed by the Mines Branch, Department of Mines,

at Ottawa, these samples gave the following results:—

Sample.	A.	B.
Water	5·95	5·29
Volatile combustible matter.	40·46	36·14
Fixed carbon	45·16	40·12
Ash	8·43	18·45
	100·00	100·00
Coke per cent	53·59	58·57
Character of coke	Firm, coherent.	....
Ratio of volatile combustible to fixed carbon	1 to 1·11	1 to 1·11
Colour of ash	Reddish.	Reddish.
Kind of fuel	Coal.	Coal.

From Five Fingers mine to Five Fingers rapids the rocks along the river are mainly the Laberge Jura-Cretaceous sediments, but in places volcanics of Mesozoic or Tertiary age occur.

337 m.
539 km.

Five Fingers Rapids—Five Fingers rapids are caused by heavy beds of coarse conglomerate of the Laberge series, which cross the river at that point. At one time, a fall probably existed there, but the barrier has now been cut through at several points, giving the rapids the appearance intended to be conveyed by their name. The massive rock buttresses and the narrow tongues or rushing water between, have a formidable appearance. River steamers, however, go through without much difficulty at most seasons, but when the water is high, upstream boats have to be lined through with a cable attached to the bank above.

343 m.
548 km.

Rink Rapids—Rink rapids have more the appearance of a broad stony riffle than a rapid, although, especially in high water, the current

Steamer Whitehorse in the Five Fingers rapids.

is swift, being probably about 8 miles (13 km.) per hour.

From Rink rapids to Selkirk, the Lewes is remarkably straight and follows a general course of about S 50° W, the current averaging about 4½ miles (7 km.) per hour. This stretch of the river, more so than most portions of the stream above, contains a large number of islands which are somewhat conspicuous in that they characteristically occupy positions in midstream. The valley is generally wide, and the hills bounding it seldom exceed 1,000 feet (300m.) in elevation above the river. Terraces are prominent, and in most places are from 100 to 200 feet (30 to 60 m.) above the stream.

An exposure of boulder clay occurs a short distance below Rink rapids, and is the most northerly occurrence of this material noted on the Lewes. This point is probably near the limit of glaciation in the Lewes River valley. Glacial striæ several hundred feet above the river were noted along Nordenskiöld river near Carmack, but are not known to have been seen farther down the Lewes.

Rock exposures are infrequent along the portion of the river between Rink rapids and Selkirk. In a few places the slopes of the hills run down to the waters' edge, and it is generally only at such points that rock outcrops occur. Jura-Cretaceous sediments, however, appear to continue downstream on the right limit of the river to below Yukon Crossing.

347 m. **Yukon Crossing**—Altitude 1,597 ft. (485m.)
555 km. Yukon Crossing is the point where the Whitehorse-Dawson wagon road crosses Lewes river, and is 144 miles (230 km.) from Whitehorse, measured along the road. During the winter months, stages carrying passengers and mail, make regular trips between Whitehorse and Dawson, crossing the river at Yukon Crossing on the ice. During the season of open navigation on the river, this road is little travelled, and the river is crossed at Yukon Crossing by means of a ferry.

The hills immediately behind the road-house at Yukon Crossing, consist of dark greenish andesitic rocks which appear to be somewhat extensively developed in that locality. Below Yukon Crossing, 5 and 6 miles respectively (8 and 9·6 km.), Merritt and Williams creeks join the Lewes on its left limit. Up these creeks and within a distance of 3 miles (4·8 km.) from the river, a number of copper claims have been located and have been more or less developed [**12**]. The rocks throughout the Williams and Merritt Creeks area, and for several miles at least down the Lewes, are mainly much altered, dark green, sheared eruptives and granitic rocks. The older sheared members have a pronounced schistose structure and belong to the older pre-Ordovician rocks. These have been here so extensively invaded by the granitic intrusives, that the two appear to be about equally extensive in this vicinity.

Hoo-che-koo bluff [**28,** p. 144B-146B], which is situated on the right limit of the river about 11 miles (17·5 km.) below Yukon Crossing, and which is the abrupt face of an isolated hill against which the river washes, consists of a grey, slightly porphyritic, felspathic rock which is interbedded with fine grained, nearly black argillite. These rocks are much fractured and distorted, and probably are of lower Paleozoic age.

Below Hoo-che-koo bluff for about 25 miles, (40 km.) the few rock exposures along the river consist mainly of diabase or diorite and diabase agglomerates. About 10 miles (16km.) above Selkirk some greyish granite outcrops, which in places contains large porpyhritic feldspar crystals. This granite is similar to that in the vicinity of Williams and Merritt creeks, and is probably related to the Coast Range granitic intrusives.

Commencing about 6 miles above Selkirk, the Tertiary basalts are again developed, and from there extend downstream for over 30 miles (48 km.) Several superimposed flat-lying flows occur, giving rise to a wide basalt plateau.

Bituminous coal of good quality has recently been discovered about 5 miles (8 km.) above Selkirk in the bank on the left limit of the Lewes river in rocks apparently of Jura-Cretaceous age, underlying the basalt flows. As no development work has yet been performed, the number and thickness of the coal seams have not yet been determined.

393 m.
628 km.

Selkirk—Altitude 1,555 feet (472 m.) Selkirk is the site of an old fort, and is now a trading post and Indian village. It is situated on the left limit of Yukon river just below the confluence of Lewes and Pelly rivers.

Yukon river from Selkirk to Dawson is liberally strewn with islands, and to White river has a current of about 5 miles (8 km.) per hour. The valley throughout this distance is from 800 to 1,000 feet (240 to 300 m.) or more in depth, and has a trend slightly north of west.

For about 25 miles below Selkirk the basalt plateau continues on the right limit of the river, the vesicular lavas overlying older schistose rocks which continue downstream to Dawson. On the left limit of the river these older rocks extend from Selkirk to Dawson. Except for the lavas, the predominant rock between Selkirk and White river consists of a hard, granular, well foliated mica-gneiss. Hornblendic, micaceous, and chloritic schists are also well represented.

491 m.
785 km.

White River—White river is a turbid stream carrying sufficient sediment to change the colour of the whole Yukon below the confluence. White river joins the Yukon on its left limit, and 10 miles (16 km.) below its mouth.

501 m.
801 km.

Stewart River—Stewart river enters from the right. From Stewart river to Dawson the valley of the Yukon "is cut through an elevated undulating plateau, on which rest numerous low ranges of rounded and partly bare hills,

Typical scene on Yukon river near Selwyn.

but is not crossed by any well defined mountain range. It is somewhat uniform in appearance, but affords many picturesque and even grand views. Bluffs of rock of a more or less precipitous nature, are of constant occurrence, and bold rampart-like ranges of interrupted cliffs, separated and continued upward by steep grassy or wooded slopes, characterize the banks for long reaches. The flats are few and unimportant, and as a rule the river washes the base of the banks on both sides. The width of the valley varies from one to three miles (1·6 to 4·8 km.), and its depth from five to fifteen hundred feet (150 to 450 m.). Its great size, taken in connection with the hard character of the crystalline rocks through which it has excavated, afford evidence of great age, and point to an origin long antecedent to the glacial period." [**50,** p. 141 D.]

Sections of the rock formations are numerous along the valley, but the geology is intricate and difficult. The predominant rocks are schistose and gneissoid types and crystalline limestone all of lower Paleozoic age or older, which correspond to McConnell's Nasina series, Klondike series, and Moosehide diabase of Klondike district. [**51,** pp. 10 B-23 B]. In places these older rocks have been invaded by various intrusives mainly granite and diabase.

524 m.
838 km.
Sixtymile River—Sixtymile river joins the Yukon from the west about 23 miles (36 km.) below the mouth of the Stewart. About 17 miles (27 km.) below the mouth of Sixtymile, some sandstones and shales, thought to be of early Tertiary (Kenai) age, occur intimately associated with andesitic and rhyolitic volcanics, and outcrop along the left limit of the Yukon for about 7 miles (10 km.). [**51,** p. 24B]. These rocks have a considerable development to the west along Sixtymile river.

571 m.
913 km.
Dawson—Altitude 1,049 feet (318 m.) Dawson is the principal town in Yukon and is the seat of the Territorial Government. It is

Dawson.

situated on the right limit of the Yukon at the confluence of Klondike river, and is 334 miles (534 km.) from Whitehorse measured along the waggon road or 460 miles (736 km.) by river.

KLONDIKE GOLD FIELDS.*

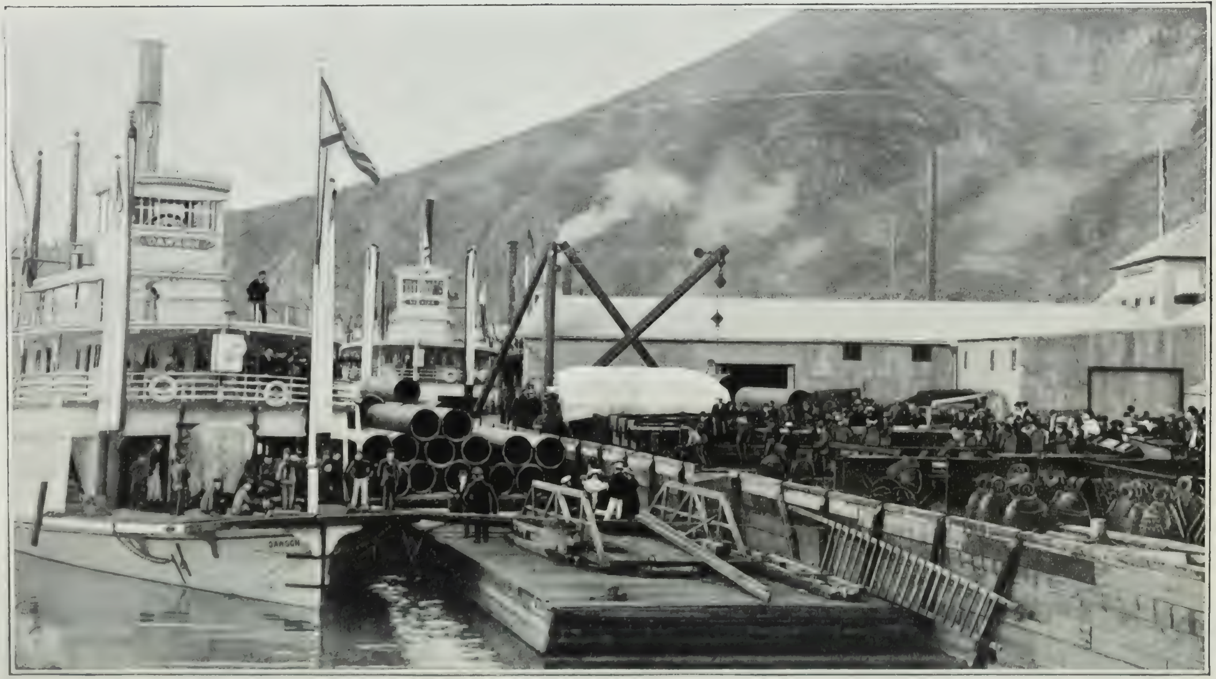
General Description.

Klondike gold fields are situated in Yukon Territory, on the east side of Yukon river, at the confluence of the Klondike, and at about 64° north latitude. The district comprises approximately 800 sq. miles (2,000 sq. km.) and is bounded in a general way by Yukon river on the west, by Klondike river on the north, by Flat creek, a tributary of the Klondike, and Dominion creek, a tributary of Indian river, on the east , and by Indian river on the south.

Topographically, the area included within the Klondike gold fields, is a typical example of a thoroughly dissected upland, and is situated well within the Yukon Plateau physiographic province. Klondike district is underlain by a complex of rock formations ranging in age through the greater part of the geological scale, and presenting extreme variety in structure and composition. The rocks consist dominantly, however, of various schistose members that have generally been considered to be of lower Paleozoic age, but may be Pre-Cambrian. These have been repeatedly pierced by igneous intrusives at widely separated periods. The older rocks are in places underlain by Tertiary sediments and superficial accumulations.

Economically the district is mainly of importance on account of the rich and extensive deposits of gold-bearing gravels which it contains. Placer gold was first found in the Klondike in 1894, and since 1896 this district has been one of the greatest and most widely known placer gold camps in the world. At present the bulk of the placer properties are worked by companies who have spent millions of dollars in equipment and installation, and are obtaining the gold mainly by dredging and hydraulicking. In a few places, however, individual miners still work their

*The general description here given of the Klondike Gold Fields, is to a considerable extent summarized from Mr. McConnell's reports on the district. (51. 58.) The parts, however, dealing with the recent developments, methods of working, equipment, installations, etc., are the result of personal investigations by the writer.



A typical scene on the Dawson wharf during the summer season.

own claims and employ the somewhat primitive old-time methods that were so common a few years ago.

The streams flowing through the area are all gold-bearing to some extent, but only a limited number have proved remunerative. The most productive streams are: Bonanza creek with its famous tributary, Eldorado creek; Bear creek and Hunker creek, flowing into the Klondike; and Quartz creek, and Dominion creek, with Gold Run and Sulphur creeks, tributaries of Dominion creek, flowing into Indian river.

A considerable number of quartz properties are held in different parts of Klondike district and some have been more or less developed. None of them can as yet be considered to have passed the prospect stage.

Topography.

Topographically, Klondike district is a typical example of a thoroughly dissected upland. It forms part of the Yukon plateau, which is thought to have been originally part of a great peneplain, at one period of its history elevated so as to constitute a high plateau and subsequently deeply trenched by the various streams by which it is drained. In the Klondike, at least, a second uplift has occurred in comparatively recent times, resulting in a further deepening of the valleys 300 feet to 700 feet (150 to 210 km.). Portions of the old valley bottoms, still covered with heavy accumulations of gravel, remain at many points, forming terraces of various widths, bordering the newer valleys.

Viewed from a distance, Klondike district has a hilly or even mountainous aspect, but in reality consists of a series of long branching ridges, the summits of which have been carved irregularly into hill and hollow by unequal denudation. Most of the ridges originate at or near the Dome, the topographic centre of the district, and the highest point in it.

The Dome is situated 19 miles (306 km.) southeast of Dawson, and about midway between Indian and Klondike rivers. It has a height of about 4250 feet (1295 m.) above the sea, 3050 feet (930 m.) above Yukon river at Dawson, and about 500 feet (152 m.) above the ridges at its base. It is not conspicuously higher than the other hills in the neighbourhood, and the gradual decrease in height out-

A steamer with barge attached starting down river from Dawson.

wards along the ridges radiating from it, is scarcely noticeable to the eye. The Dome is the principal drainage centre of the district. From it, Allgold and Dominion creeks flow eastward, Quartz and Sulphur creeks southward, and Goldbottom and Hunker northward. The ridges separating these streams, although deeply and repeatedly gashed by tributary valleys, are unbroken, and it is possible, starting from the Dome, to reach any part of the district without descending into the valleys. Subordinate drainage centres occur at other places.

General Geology.

Klondike district is underlain by a complex of rock formations ranging in age through the greater part of the geological scale and presenting extreme variety in structure and composition. The region has been repeatedly broken through by igneous intrusions at widely separated periods, and has been subjected to enormous pressure from earth movements. Alterations in the character of the rocks, induced by dynamic and associated metamorphic agencies, have proceeded to an extreme degree. Massive igneous rocks have been sheared and crushed into finely foliated schists, and the clastics in many places recrystalized to the semblance of igneous rocks. The oldest and most important formations consist of ancient schists, partly of clastic and partly of igneous origin.

The southern part of the district is underlaid by altered sedimentary rocks, now represented dominantly by quartz-mica-schists and crystalline limestones. These are bordered on the north by a wide band of light-coloured, in places almost white, sericite-schists alternating occasionally with greenish chloritic schists. All these various types of schists have been derived from igneous, and largely from massive igneous rocks. The principal producing creeks of Klondike district occur in the area occupied by them. The sericite-schists and associated rocks are replaced near the mouth of Klondike river by green diabase rocks, which are usually schistose in structure, but in places might almost be termed massive. These diabase rocks are everywhere greatly altered and, on Moosehide mountain pass into serpentine. East of the diabase and serpentine area on Moosehide mountain, the sericite-schists alternate on the north with bands of dark quartz-mica-schists, very similar to those bordering them on the north.

The old schist floor of the district is penetrated at numerous points by intrusives belonging to several groups. A massive, coarse-grained, grayish granite resembling the Coast Range granites, cuts the sedimentary schists in Yukon river below Indian river. Serpentine, derived in part, at least, from peridotites, occurs at several points on the crest of the ridge separating Hunker creek from the Klondike, and numerous small, usually oblong areas of comparatively recent rhyolites and andesites are scattered irregularly throughout the district. Massive diabases occur on Indian river below New Zealand creek, and in dykes in the Yukon valley opposite Indian river, and on Eldorado creek. Unaltered sedimentary rocks consisting of clays, shales, sands, sandstones, tuffs and conglomerates nearly destitute of determinable fossils, but probably of Tertiary age, overlie the schists in the lower part of the valley of Last Chance creek, and in separate depressions at several points around the outskirts of the district. These recent sedimentary rocks are associated in every area with dykes, stocks, and sheets of andesite, and in places, with dykes and small areas of diabase.

As Klondike district has not been overridden by ice, the surface rocks, as is usual in unglaciated regions, are deeply weathered. A thick covering of decomposed schist, usually intermingled with the slide rock, mantles the sidehills nearly everywhere. On the ridges the covering is less, and the schists, often worn into fantastic shapes, in places project above the general surface, or are exposed along the sides of the steeper hills.

The surface materials are also permanently frozen. The thickness of the frozen stratum varies considerably, and is less on the ridges than in the valleys, and less also on southern than on northern exposures. A shaft on the ridge south of Eldorado creek reached unfrozen ground at 60 feet (18·2 m.), while one in the valley of Eldorado creek was stopped by running water at a depth of over 200 feet (61 m.) Another shaft, sunk through gravel on the plateau between Bonanza and Klondike river, passed through the frost line at a depth of 175 feet (53·3 m.). The summer heat has little effect on the frozen layer, except in the few places where the surface is unprotected by moss. Exposed gravel beds in favourable positions thaw out to a depth of 4 to 10 feet (1·2 to 3·0 m.), but where moss is present, frost is always encountered close to the surface.

A section across the valley of any of the gold-bearing streams entering the Klondike shows a comparatively narrow, trough-like depression below, 150 to 300 feet deep (45 to 90 m.), bordered on one or both sides by wide benches beyond which the surface rises in easy, fairly regular slopes up to the crests of the intervening ridges. The benches represent fragments of older valley bottoms partly destroyed by the excavation of the present valleys. Narrow rock-cut terraces occur at intervals between the level of the old valley-bottoms and the present level. Auriferous gravels occur on the present valley-bottoms, on the portions of the old valley-bottoms still remaining, and on the rock terraces cut into the slopes connecting them. These deposits may be classified as follows.—

Low level gravels { Gulch gravels
Creek gravels
River gravels.

Gravels at intermediate levels. Terrace gravels.

High level bench gravels { Klondike gravels
White Channel gravels.

The low level creek gravels are the most important gravels in the district, and floor the bottoms of all the valleys to a depth of 4 to 10 feet (1·2—3·0 m.). They rest on a bedrock usually consisting of decomposed and broken schists, and are overlaid by a sheet of black frozen muck ranging in thickness from 2 to 30 feet (·6 to 9 m.) or more. They are local in origin and consist entirely of the schists and other rocks outcropping along the valleys. The schist pebbles are usually flat, round-edged discs measuring from 1 to 2 inches (25 to 50 mm.) in thickness and from 2 to 6 inches (50 to 150 mm.) in length. These pebbles constitute the greater part of the deposits, but are associated with a varying proportion of rounded and subangular quartz pebbles and boulders, and, less frequently, with pebbles derived from the later eruptive rocks of the region. The pebbles are loosely stratified, usually embedded in a matrix of coarse reddish sand, and alternate in places with thin beds of sand and muck. These gravels frequently enclose leaves, roots and other vegetable remains, and the bones of various extinct and also existing types of northern animals, such as mammoth, mastodon, buffalo, bear, musk-ox and mountain sheep.

The gulch gravels occupy the upper portions of the main creek valleys and small tributary valleys, and differ from the creek gravels in being coarser and more angular. A considerable portion of their material consists of almost unworn fragments of schist washed down from the adjacent slopes. They contain the same vegetable and animal remains as the creek gravels.

The only river gravels of the district proven, so far, to contain gold in paying quantities, occur in the wide flats bordering the lower portion of Klondike river below the mouth of Hunker creek. The river gravels consist of quartzite, slate, chert, granite and diabase pebbles, which are harder and more rounded than the creek gravels, as a result of the greater distance travelled.

Rock terraces cut into the steep slopes of the present valleys occur at different points. They were produced during the deepening of the valleys, and are simply remnants of former valley bottoms. They are small, seldom exceeding a few yards or metres in width, and a few hundred yards in length. They are also irregular in distribution, and occur at all elevations up to the bottoms of the old valleys. The terraces are beds of gravel, usually from 6 to 15 feet (1.8 to 3.6 ,m) in thickness, very similar to that in the creek bottoms, but showing somewhat more wear. The terrace gravels, like the creek gravels, are overlaid as a rule, with muck, and at one point on Hunker creek, were found buried beneath a hundred feet of this material

High level gravels are extensively distributed along Bonanza and Hunker creeks and some of their tributaries, and also occur on Eldorado, Bear, Quartz, Ninemile, and Allgold creeks. They consist principally of ancient creek deposits, overlaid near the mouths of some of the valleys by gravels laid down by Klondike river, when it ran at a much higher level than at present, and occupied a somewhat wider valley.

High level river gravels occur at various points along Klondike river, and in most places are found at elevations of 200 to 300 feet (60 to 90 m.) above the valley flats. These gravels differ altogether in character and appearance from the White Channel gravels of the creeks. The pebbles are smaller and more rounded, and consist mainly of slate, diorite and quartzite, derived, like those of the present stream gravels, from the mountains of the Ogilvie range. The Klondike gravels as a rule have only a small gold content, but below the mouth of Bonanza creek, they have

been enriched and in places contain gold in commercial quantities.

The White Channel bench or hill gravels are the oldest in the district, and, excepting the present creek gravels, are the most important from an economic standpoint. They were originally creek gravels, deposited in a similar manner to those at present occupying the low levels, and their elevated position is due to an uplift which affected the whole region bordering the Yukon from Stewart river northwest to the Alaskan boundary and for a considerable distance beyond. This uplift, and a slight depression which preceded it, produced many notable changes in the topography of the country. The White Channel gravels, however, differ somewhat from the ordinary type of stream deposit. They are very compact as a rule, and in some of the hydraulic cuts stand up in almost vertical cliffs, even when the face is unfrozen. The white or light gray coloration from which these gravels derive their name, is very conspicuous in most of the sections, but is not universal, as red, yellow, and dark gray beds frequently occur. The deposit is highly siliceous, the principal constituent consisting of rounded pebbles and rounded and subangular boulders of vein quartz. Flat schist pebbles and boulders, usually in a more or less advanced stage of decomposition, occur with the quartz, as also do occasional pebbles derived from the various dikes and stocks outcropping along the valleys. The pebbles and boulders seldom exceed 18 inches (.5 m.) in diameter, and are embedded in a compact matrix consisting essentially of small sericite plates and fine angular quartz grains. A few large angular blocks from 3 to 4 feet (.9 to 1.2 m.) in diameter occur in places but are rare and generally near bedrock.

The White Channel gravels are strikingly uniform in composition and general character, and as a rule the bedding planes are inconspicuous. Their range in thickness is from a few feet to 150 feet (1 to 45 m.), and the original width from 200 yards to over a mile (180 m. to over 1.6 km.). Unlike the creek and gulch gravels they appear to be destitute of vegetable and animal remains.

In places the typical compact variety of the white Channel grave s is replaced toward the sides of the old valley by flat rusty coloured gravels, more loosely bedded and containing a smaller proportion of quartz than the ordinary white variety. These probably represent flood plain deposits and are seldom productive.

The White Channel gravels were probably deposited by winding streams with easy grades and comparatively slack currents. The predominance of vein-quartz pebbles and boulders, the most resistant rock in the district, gives them the character of a residual deposit. They were built up slowly, and in the long process the softer rocks were mostly destroyed and carried away. The age of these deposits has not been determined, but they must have been formed at least as early as the Pliocene.

The gold of the Klondike placer deposits varies greatly in fineness, not only on different creeks but also along different portions of the same creek, due to its being in all cases alloyed with silver in varying proportions. The lowest grade gold in the camp has a value of about $12.50 per ounce, and some of the gold obtained from Upper Hunker creek has exceeded $17.50 per ounce.

The variation in the fineness of the placer gold appears to depend mainly on original differences in the vein gold from which it was derived. Creeks draining certain areas in the district carry low grade gold, while other areas supply high grade. While the fineness of the placer gold is thus supposed to conform n a general way with that of the original vein gold, some changes are evidently produced by the leaching out of a portion of the silver contents

Placer Mining Operations.

General.—In a few localities, as on Quartz creek, along the lower portion of Sulphur creek, and on a few outlying creeks, private parties are working their properties with small outfits, and there, the old-time methods, formerly so extensively employed are still to be seen. Throughout the greater part of the district, however, the placer deposits are owned and operated by large companies or corporations who work their holdings on an extensive scale. The larger companies are the Yukon Gold Company, Boyle's Concession Limited, and a company controlled by Mr. A. N. C. Treadgold. These companies control the bulk of the placer property in Klondike district, and in attempting to give a general description of the placer mining operations in Klondike district, possibly the best and simplest manner of so doing will be to describe briefly the installation and work of each of these companies.

Shovelling-in on Dominion creek.

In mining in this district many changes were necessarily introduced in adapting to the frozen gravels of Yukon the placer mining methods previously understood and employed in California and other temperate climates. The dredges had to be strongly built in order to withstand the severe service of digging the broken schists which compose the bedrock, and the frozen gravel which is almost as impenetrable as granite. Probably the most serious problem, however, was to overcome the frozen condition so that the material could be handled as readily as similar ground in California or elsewhere. These matters are of intense interest to the mining engineer.

The Yukon Gold Company.—The Yukon Gold Company owns practically all the more important gravels on Bonanza, Eldorado and Hunker creeks and their tributaries, the holdings of the company being mainly included in an area about 25 miles (40 km.) in diameter.

The operations of the Yukon Gold Company in Klondike district are, in general, limited to two phases of placer mining, viz., dredging and hydraulicking. The gravels in the valley bottoms are all dredged, but those higher up on the hills and sidehills, which cannot be conveniently reached by the dredges, are hydraulicked, and in general the lower deposits are first worked so as to afford tailings ground when working the higher gravels. During the season of 1912 an average of about 600 men were employed by this company, 400 of whom were engaged in connection with dredging, about 130 on the hydraulic properties and ditches supplying these with water, and the rest were employed mainly in the machine shops, power plant and stables.

The Yukon Gold Company has built and is operating eight dredges, as follows:—

Three Bucyrus	5-foot boats,
One Marion	7-foot boat,
Four Bucyrus	7-foot boats.

The 5-foot and 7-foot boats have buckets with a capacity of 5 and 7 cubic feet respectively (·14 and ·19 cubic metres). All are electrically driven, elevated, close-connected bucket-line dredges of the revolving screen and stacker type. Two of the boats, numbers 8 and 9, which were built during 1911, have hulls constructed entirely of steel.

A dredge in the process of construction.

The dredging season opens about May 1st and the dredges can operate from then until some time between October 15 and November 1, an average of about 175 days each year.

The capacity of the dredges on the creeks in which they are working, has proved to be about 100,000 and 120,000 cubic yards (76,000 and 91,000 cubic metres) per month for the 5-foot and 7-foot boats respectively. The area they cover depends largely on the depth of the ground in which they are working. During 1912, however, the 5-foot boats covered, on an average, about 12,000 square yards (10,000 square metres), and the 7-foot boats an average of about 16,500 square yards (14,000 square metres) per month. The dredges run day and night, and shut down only for repairs or to clean up, the latter being necessary about every 3 to 9 days.

The ground to be dredged is all previously thawed. In some areas, as in the neighborhood of a creek, or where the moss has in some way become stripped off the surface, the ground has become naturally thawed. In places, also, the gravels have been thawed during former mining operations, but the greater part of the ground is thawed by steam just previous to dredging. Long, hollow, perforated steel tubes with sharpened points are driven into the ground, and steam is forced through these and into the surrounding frozen ground.

The dredges take up, in addition to the gravels and overburden, the underlying bed rock to a depth of 3 to 9 feet (·9 tp 2·7 m.).

The properties on which the Yukon Gold Company's dredges were situated near the close of the season of 1912 are as follows, and in all probability these boats will be very close to these positions during 1913:—

No. 1.—5-foot Bucyrus boat, on No. 97 below Discovery on Bonanza creek.*

No. 2.—5-foot Bucyrus boat, on No. 60 below Discovery on Bonanza creek.

Nos. 3 and 6.—5-foot and 7-foot Bucyrus boats, on No. 76 below Discovery on Bonanza creek.

No. 4.—7-foot Marion boat, on the Anderson Concession on Hunker creek.

No. 5.—7-foot Bucyrus boat, on No. 17 below Discovery on Bonanza creek.

*For these positions, see map accompanying R. G. McConnell's report 58.


MAP OF
MAIN LINE DITCH
FROM
TWELVE-MILE RIVER TO BONANZA CREEK
YUKON TERRITORY
Ogilvie Range
TOMBSTONE
LIGHTHOUSE MTN
LONE MTN.
POWER HOUSE
SLATE
CREEK
DIVISION
ELECTRIC TRANSMISSION LINE
Rock Creek
ROCK CREEK DITCH
Low Divide
BALLARAT PIPE LINE
KENTUCKY POINT DIV.
TWELVE MILE DIVISION
SAW MILL
Twelve-mile
River
GROUSE MTN
BOYLE
CONCESSION
Klondike River
DAWSON
Yukon
River
MOOSEHIDE
Scale
MT THOMAS
Thomas G.

No. 8.—7-foot Bucyrus boat with steel hull, on No. 10 above Discovery on Upper Bonanza.

No. 9.—Sister boat of No. 8, on No. 10 Eldorado creek.

In connection with the hydraulic operations of the Yukon Gold Company, one of the greatest problems originally confronting them, was that of obtaining sufficient water to work their properties. To obtain this water a giant ditch system has been constructed and a storage dam built.

The storage dam, situated on Upper Bonanza creek, is 68 feet (20 m.) high at the crest, 205 ft. (62 m.) wide at the base, and 465 feet (141 m.) long at the top, with an impounding capacity of 54,000,000 gallons (245,000,000 litres).

The main ditch conveys water from Little Twelvemile river to the creeks of the Klondike district. The main ditch system consists of 64·2 miles (102·7 km.) of main line, composed of 15 miles (24 km.) of flume, 37 miles (59 kn.) of ditch, and 12 miles (19 km.) of pipe line, crossing five depressions and delivering water to the Lower Bonanza hills under a head of 500 feet (152 m.). The capacity of the main ditch is 5,000 miner's inches. The Bonanza Extension is approximately 6 miles (9·5 km.) in length, has a capacity of 3,000 miner's inches and crosses three depressions. The total length of the ditch system and extensions is 75·2 miles (115·5 km.).

Practically the entire construction work of the Yukon Gold Company, including the ditch system, was completed in three seasons of four months each, or a little over one year of actual construction work. Considering the unusual difficulties to be overcome, this work may be justly called an engineering triumph. The Klondike syphon—the huge pipe line which carries the water across the valley of the Klondike—was itself an undertaking of considerable magnitude. Mr. T. A. Rickard in his description of this ditch system writes [**64**]: "The country traversed by this ditch is a rolling woodland indented by the alluvial flats of the Klondike, the Twelvemile, and other streams flowing into the Yukon river. As seen from a height, the wilderness stretches unbroken from the meandering shimmer of the Klondike, enclosed within high banks on which white scars mark bench-diggings, to the Ogilvie range, where, far to the north, the snow still lingers in token of the gift of water that shall enable man to win the gold from the deposits of gravel strewing the tortuous valleys."

Hydraulicing on Lovitt gulch.

In preparing to build the ditch, the first step was to place a sawmill on Twelvemile river, and thus to obtain the lumber for construction. Then an electric generating plant was erected and the wires were strung on poles for 36 miles (57 km.), transmitting power from Little Twelvemile river to Bonanza creek. While this was being done, surveys for the ditch were hastened; and as soon as these were completed, the right-of-way was cleared. The small growth of forest was removed, and the moss stripped from the frozen ground for a width of 22 yards (19 m.) Steam shovels were then put to work, and while they were digging the ditch, the sawmill on the Twelvemile yielded the lumber needed for the construction of the flume and for other purposes. Seven million feet (board measure) of lumber were cut; this depleted the small forest in the vicinity, but it proved sufficient.

In connection with building the ditch, "roads of the corduroy type have been constructed, moss being laid on the poles and dirt on the moss. The trails traverse the brush in straight lines. Horses and men, steam and muscle, have fought against the wilderness and subdued it. The big ditch looks like a Panama canal, and the steam-shovels gnawing and digging in the deep cuts recall pictures of Culebra. Many of the labourers had worked on the Isthmian canal, and assuredly the young engineers were as proud of the work they were accomplishing as if it were a national or even an international enterprise." [**64**].

About 14 hydraulic properties were operated in 1912 on the different hills and gulches along Bonanza and Hunker creeks, the majority of these being on Bonanza creek below Grand Forks. These hydraulic properties are equipped with auxiliary pipe lines from the main water system, gates, tunnels, cuts, sluiceways, and giants from which the streams of water are driven with a pressure of upward of 100 pounds to the inch (7 kilogrammes to the square centimetre) and strike the banks with a roar that can be heard for miles.

The company's hydro-electric power plant is operated by water from Little Twelvemile river carried through 5 miles (8 km.) of flume and delivered to the plant under 650 feet (197 m.) net effective head. The installation consists of three 650 K.W. generators, direct connected to three water wheels of the impulse type. The main transmission here is 36 miles (57 km.) in length, operating

Hydraulicing on American hill

at 35,000 volts with 18·2 miles (29·1 km.) of extensions and secondaries.

Boyle Concession Ltd.—The Boyle Concession Ltd., has taken over the holdings of the Canadian Klondike Mining Company; controls and operates the properties of the Bonanza Basin Gold Dredging Co.; and operates the plant of the Granville Power Company.

The holdings of the Boyle Concession Ltd. include the Boyle Concession, about 4 miles (6·4 km.) of the creek bed of Allgold creek, and 4 miles (6·4 kn.) of the creek bottom of Flat creek. The Boyle Concession comprises 6·7 miles (10·7 km.) of the valley of Klondike river to the summits on either side, also Bear creek and its hillsides, and the Klondike River slope of Lovitt hill; in all about 40 square miles (103 sq. km.). The holdings of the Bonanza Basin Gold Dredging Co. include about 50 placer claims in a group at the lower end of Klondike River valley and just below the Boyle Concession; nearly all Last Chance creek with adjoining hillsides; part of Dago hill; a number of placer claims on the upper end of Hunker creek; and some placer claims on Upper Eldorado.

The operations of the Boyle Concession Ltd., are confined at present to dredging. Two dredges were in operation in 1912, and two more were being built.

No. 1 dredge is an electrically driven boat, with a close-connected bucket-line of 68 buckets, each having a capacity of $7\frac{1}{2}$ cu. ft. (·21 cu. m.). This dredge has a total motor capacity of 350 horsepower and has been operating continuously each season since 1905. No. 2 dredge is an electrically driven boat with close-connected bucket-line of 68 buckets, each having a capacity of 16·1 cu. ft. (·45 cu. m.). This dredge has a total motor capacity of 1005 horsepower, and started operating in 1910 and has since operated continuously during the dredging seasons.

These two dredges are both operating in the valley of the Klondike on the Boyle Concession.

The two dredges being erected will be very similar to No. 2, but will have slightly larger hulls and will be equipped with some new features for protection in operating during severe weather. Each boat contains over 1,000 tons (907 tonnes) of machinery and required 612,000 feet of lumber in the building. These are being erected on the property of the Bonanza Basin Gold Dredging Co., below the Boyle Concession.

Dredge No. 2, belonging to the Boyle Concession Limited, operating on the Boyle Concession in the Klondike valley.

The Boyle Concession Ltd. has a machine shop capable of making all repairs at the mouth of Bear creek, and also owns three 35-ton steam shovels with hauling equipment, and other machinery.

The Granville Power Company has a 10,000 horsepower hydro-electric power plant situated in the valley of Klondike river near the mouth of the North fork. The water is taken from the North fork of Klondike river through 6 miles (9·5 km.) of ditch having a capacity of 15,000 to 20,000 miner's inches, and is supplied to two turbines through two pipes with an effective head of 228 feet. (69 m.).

The power plant consists of two units, and includes two I. P. Morris 5,000 horsepower wheels of the reactionary type, two alternating current generators and two excitors built by the Westinghouse Electric Manufacturing Co. The power is generated at 2,200 volts and stepped up at plant to 33,000 volts and is carried over two main distributing lines, one down Klondike river to its mouth, and the other across the divide to the Indian River watershed.

This plant ran until December 21st, 1911, and the company hopes to be able to instal devices enabling them to operate throughout the entire winter.

Treadgold Property.—A company managed by Mr. A. N. C. Treadgold holds extensive interests mainly on the Indian river side of the divide. This company controls practically all Dominion creek; has interests on Sulphur creek; controls most of Quartz creek and Indian river below Quartz creek; and also has a few claims on the upper end of Eldorado creek. During 1912 the operations of this company were mainly confined to Dominion creek, where they did only preliminary work. This consisted mainly in removing the overburden by ground sluicing and so preparing the ground for future development.

Granville Power Company's power house in the valley of the Klondike near the mouth of the North Fork.

GOLD PRODUCTION.

The placer gold production of the Yukon from 1897 is as follows:—

Yeor.	
1898	$10,000,000
1899	16,000,000
1900	22,275,000
1901	18,000,000
1902	14,500,000
1903	12,250,000
1904	10,500,000
1905	7,876,000
1906	5,600,000
1907	3,150,000
1908	3,600,000
1909	3,960,000
1910	4,550,000
1911	4,580,000
1912	5,660,000

The figures for 1912 are only approximate. The low production during 1907, 1908, and 1909 was due mainly to the fact that at that period placer mining was undergoing a transition from the old to the new methods. The Yukon Gold Company had acquired most of the ground that had formerly been the most productive, and were devoting their energies to installing their new equipment rather than to mining.

The figures given above are for the entire Yukon Territory, but the gold production from points outside of the Klondike has probably never exceeded $100,000 per year.

QUARTZ MINING—[**51, 3, 16**].

Considerable interest has of late been evinced in the quartz veins of the Klondike, and special efforts are being made to develop the lode mining of this district, in the hope that a revenue may eventually be derived from this source that will continue to foster the mining industry of this portion of the Yukon when the placer deposits have become exhausted, which it is thought, however, will not be for many years yet to come.

A great amount of quartz occurs in the old schistose rocks that are so extensively developed in Klondike dis-

A property on Hunker creek, being worked by individuals by means of a self-dumping equipment.

tricts, and in some localities it is in sufficient quantity to even constitute a considerable proportion of the whole rock mass. The quartz occurs prevailingly in veins which exhibit considerable variety of form and are as a rule small and non-persistent, but range in size from mere threads to masses several hundred feet in length, but in most p aces less than 10 feet (3 m.) in thickness.

The quartz veins are characteristically but slightly mineralized; pyrite and more rarely magnetite occur in places in sufficient quantity to produce a reddish coloration on the exposed and oxidized portions of the veins, and in a few places the quartz contains particles of galena, chalcopyrite, and native gold.

Often fair, and occasionally even high, assays are ob tained, but, in most cases, it is not known, even approximately, what average amounts of gold the quartz contains. From the various properties that have been examined, however, it is concluded that the gold is always either associated with metallic sulphides, or is at or near the contact between the quartz and schists; in the latter case the gold is found in both vein material and wall rock.

A considerable numbeı of quartz claims have been located in the district. Among the more promising properties now being held, and those on which the most energy has been expended are:—the Lone Star group, near the head of Victoria gulch, a tributary of Bonanza creek; the Violet group, situated along the divide between Eldorado and Ophir creeks; the Mitchell group on the divide between the heads of Hunker and Goldbottom creeks; the Lloyd group and neighbouring claims situated along the divide between the heads of Green gulch and Caribou gulch, tributaries respectively of Sulphur and Dominion creeks; and several groups of claims on Bear creek near where joined by Lindow creek. Of these the only properties on which any development has been performed, other than the necessary assessment work, are the Lone Star and Violet groups.

No work has been performed on the Violet group for several years, but it is claimed that over $60,000 had been spent in developing the property previous to 1910.

On the Lone Star group several hundred feet of work has been performed in the form of open-cuts, trenches, shafts and tunnelling. A four-stamp Jos' ua Hendry mill has also been erected on the property, and a gravity tramway 3500 feet (1064 m.) long has been constructed to convey

the ore from the workings to the mill on the creek 900 feet (270 m.) below. In addition, a power line 4 miles (6.4 km.) long has been built to convey power to the mill from the power line of the Northern Power and Light Company on Bonanza creek.

The total gold production from this property has so far been small, and not nearly enough to pay for the development work. All these properties therefore, however promising their character, have still to be considered as being in the uncertain prospect stage.

JUNEAU-YAKUTAT SECTION.

BY

LAWRENCE MARTIN.

INTRODUCTION.

The Juneau-Yakutat section of C 8 excursion includes the steamer journey from Juneau to Yakutat bay and return, and also a stop-over of two or three days at Yakutat bay, and a few hours stop at Glacier bay. Short excursions can be made on foot and by boat while at Yakutat bay to examine interesting points along Malaspina glacier and elsewhere in the vicinity. Between Juneau and Yakutat the coast line with its glaciers can be viewed at close range from the steamer; in addition it is intended to land in Glacier bay for a few hours and examine the front of Muir glacier.

This excursion should prove of interest and value to glacial geologists and physiographers, for possibly in no part of the world can glaciers and glacial activity be as well observed and on so tremendous a scale.

The subject matter of this section is largely new material but a part is condensed or abstracted from reports by the late R. S. Tarr and the author, actual quotations being made in a few places from our published reports in the U. S. Geological Survey professional papers, and our forthcoming book on research work in Alaska for the

National Geographic Society. The author is indebted to Mr. Henry Gannett, chairman of the Research Committee of the National Geographic Society, for permission to reproduce the accompanying copyrighted topographic maps of Hidden glacier, Nunakak glacier and of Turner, Hubbard and Variegated glaciers and some of the photographs which are from the book of our investigations for the Society on the Yakutat and Glacier Bay regions.

ANNOTATED GUIDE.

0.0 m.
0.0 km.
Juneau—Leaving Juneau the steamer proceeds westward across the lower end of Lynn canal toward the entrance to Icy strait, but in so doing it follows a somewhat devious course around various points and islands.

70 m.
112 km.
Icy Strait—The route continues through Icy strait, which has a northwesterly trend. At the junction of this fiord with Lynn canal there is a discordant submarine step, Icy strait hanging above Lynn canal because of superior glacial erosion in the latter. The bottom of Icy strait slopes eastward toward Lynn canal from the Glacier Bay submarine divide, to the west of which the bottom of Cross sound slopes westward to the Pacific ocean.

Something may be seen here of the fish traps for collecting salmon.

105 m.
168 km.
Entrance to Glacier Bay—Continuing through Icy strait, the entrance to Glacier bay is reached 105 miles (168 km.) from Juneau.

THE GEOLOGY AND PHYSIOGRAPHY OF GLACIER BAY.

Rock Formations.

The rocks in the vicinity of Glacier bay are shown by the studies of H. F. Reid, [**62, 63**], H. P. Cushing [**24**], and F. E. and C. W. Wright [**88,** Plate II], to be argillites, slates, and limestones, of Paleozoic (perhaps Carboniferous) age, with diorite and other igneous rocks of Jurassic, Cretaceous, or later age.

Topography.

Glacier bay is a broadly open fiord between the Fairweather range and the mountains on the western side of Lynn canal. It is about 4 miles (6.4 km.) broad at the mouth, widens to about twice this breadth, and then branches. One arm, Muir inlet, extends due north about

Excursion C 8.

Relief map of Glacier bay and Lynn canal.

15 miles (24 km.) to the ice cliffs of Muir glacier, which surround its head, and the other arm extends northwestward for 35 miles (56 km.) where it is terminated by the Grand Pacific glacier. The latter arm is branching, with six good-sized tributary fiords also terminated by tidal glaciers. The extreme length of the bay from its mouth to the tidal front of Grand Pacific glacier is over 60 miles

(95 km.); the distance from the mouth to the head of Muir inlet is about 38 miles (60 km.).

Except at the very mouth, the entire fiord and its branches are mountain-walled though there are small areas of low-lying land along portions of the shore line. At the mouth of the bay, especially on the eastern side, there is an extensive flat extending eastward for several miles from Pt. Gustavus, and stretching northward to Beardslee islands and the neighboring coast. This low area, including the islands and associated shoals, undoubtedly has been formed by glacial deposition during a former expanded stage of the glaciers of the region. Farther up the bay the mountains rise from 2,000 to 5,000 feet (600 to 1,500 m.) within a mile or two of the fiord, and near the branching head, to elevations of 6,000 to 7,000 feet (1,800 to 2,100 m.). Complete soundings have not yet been made in this fiord, but at the narrowest part of Muir inlet there is a known depth of 618 feet (187 m.), and in the narrowest part of the northwestern arm of Glacier bay, of 720 feet (218 m.). Depths of 300 to 600 feet (90 to 180 m.) have been found in most of the soundings, and there is every reason to believe that the waters of the bay are prevailingly deep. Yet there are numerous rock islands, especially in the broader part of the bay below Muir inlet and the northwestern arm.

This fiord and its branches have a noble setting; not only are the fiord walls steep and lofty, but the background rises still higher into the perpetual snows. In a great semicircular area are lofty, snow-covered peaks and broad expanses of snowfields, from which innumerable glaciers descend toward the inlet and its several branches. The most extensive continuous snowfield is around the head of Muir inlet; but the loftiest and grandest mountains lie to the west and northwest where Fairweather, Grillon, and other peaks of the Fairweather range rear their summits to elevations of 12,000 to 15,330 feet (3,600 to 4,660 m.).

Present-Day Glaciers.

From these vast, encircling snowfields come scores of valley glaciers which unite finally into a few main ice tongues. There are now twelve tidal glaciers in this inlet, and there are a number of other ice tongues ending on the land, which have recently become independent by recession

of the main glaciers to which they were formerly tributary. One by one the tidal glaciers have been severed by recession, a continuation of which has forced their fronts back toward the inlet heads. From the ends of the non-tidal ice tongues innumerable streams flow down over the land; and from the tidal glacier fronts icebergs are discharged into the sea,

Muir glacier in 1911.

littering the fiord waters with floating ice, which in places seriously interferes with navigation, even with small boats. This is especially true toward the head of the northwestern arm of the bay, but floating ice is found throughout the inlet, and some even escapes from the bay into Icy strait.

Although the topographic conditions in the mountains back from Glacier bay are known only in general, it is possible to divide the glaciers into three groups. The first of these ncludes the Muir glacier and the Carroll and Rendu glaciers to the west; the second, fed mainly from the Fairweather range, includes the Grand Pacific, John Hopkins, Lamplugh, and Reid glac'ers; and the third, fed from the mountains between Brady glacier and Glacier bay,

includes the Hugh Miller, Charpentier, Geikie, and Wood glaciers. The excursion will visit only Muir glacier, so the others will not be discussed further.

Muir glacier [**62, 63**] is by far the largest and most important glacier of the region. It is fed from a broad, semi-circular snowfield area, above which rise mountains 5,000 to 7,000 feet (1,560 to 2,700 m.) in height. Other

Muir glacier on 1911. Ice resting on outwash gravels containing logs. Nearly 8 miles north of position of ice front of 1899. The ice here was over 1,200 feet thick in 1892.

glaciers descend northward and eastward from this area to Lynn canal and from the valleys which extend northwestward from its head. Davidson glacier is one of these. A very large number of ice tongues from this snowfield unite in a mountain-enclosed amphitheatre to form the broad ice field of Muir glacier, with mountain peaks and ridges rising above the ice surface. The total drainage area of Muir glacier is about 800 square miles (2,000 sq.km.), with over 350 square miles (900 sq. km.) of glacier surface, the two main tributaries having lengths of 20 and 22 miles (32 and 35 km.).

Historical Statement of Studies of Muir Glacier.

The first description of the region is that given by Vancouver, of Lieutenant Whidbey's observations in 1794, when the glacier front seems to have been out as far as the Beardslee islands. The region was visited by Lieutenant Wood in 1877 and by John Muir in 1879 and 1880, at which time the glacier since named Muir glacier terminated in Muir inlet. The first geologist to observe and describe it was Lamplugh in 1884; C. F. Wright spent a month studying Muir glacier in 1886 and presented the first fairly full description. I. C. Russell spent a few hours in Muir inlet in 1890, and in 1890 and 1892 H. F.

Stumps of buried forest, Muir inlet, Glacier bay.

Reid made extensive surveys, on the basis of which he has published by far the most comprehensive account of Muir and the other glaciers of Glacier bay [**62, 63**]. In this, for the first time, the other glaciers are described and mapped. H. P. Cushing, who accompanied Reid on the 1890 expedition, has also written upon the region [**24**]. The Canadian Boundary Commission mapped the region

in 1894, and Otto Klotz has written about the glaciers, particularly about the great recession. The Harriman expedition visited the bay in 1899, and G. K. Gilbert [**31**] has discussed the phenomena observed; while Henry Gannett and John Muir have presented briefer accounts. C. L. Andrews [**1**] visited and described Muir glacier in 1903. F. E. and C. W. Wright [**95**] studied and mapped the glaciers in 1906, but have not as yet published their full report. In 1907 the Boundary Survey made a new map of the Glacier Bay region. Fremont Morse [**60**] and Otto Klotz [**38**] have described the condition of the glacier in that year. Tarr and Martin [**77**] made a brief study of Muir glacier in 1911. Thus we have a fairly full record of the conditions at Muir glacier from 1879 to 1911.

Glacier History similar to that of Yakutat Bay.

The history of Muir glacier and the other ice tongues of Glacier bay is strikingly similar to the glacial history of Yakutat bay. There was (*a*) an ancient period of expansion of the glaciers, followed by (*b*) a great recession during which Muir glacier was even smaller than at present. Then came (*c*) a second period of expansion, followed by (*d*) the modern recession, which is still in progress. This modern recession has not yet been interrupted by such a great series of forward movements as the recent advances of nine glaciers in Yakutat bay, though (1) Muir glacier advanced slightly between 1890 and 1892, (2) Rendu glacier pushed forward about 1½ miles (2·4 km.) between 1907 and 1911, and (3) an unnamed, adjacent, cascading glacier advanced over 1,300 feet (395 m.).

The evidence of the ancient expansion is found in the glaciated topography and the glacial deposits of the fiord. The proof of the ensuing recession comes from the buried forests. There are trunks of mature trees in deposits which rest upon glaciated surfaces, some logs found by Tarr and Martin being as far north as the ice front of 1911. The second expansion is indicated by the youthful vegetation of southern Glacier bay and by the historical observations of Whidbey and Vancouver in 1794.

The stages in the modern recession are summarized in the following table:—

Year.	Movement.	Amount.	Rate per year.	Based on Observations by
Before 1794 .	Advance...	34+miles (54 km.)	....	Vancouver and Whidbey.
1794 to 1880.	Retreat....	24+miles (38 km.)	1,488 ft. (452 m.)	Muir.
1880 to 1884.	Retreat....	....	....	Lamplugh.
1880 to 1886.	Retreat....	4,000 ft. (1,200 m.)	666 ft. (202 m.)	G. F. Wright.
1886 to 1890.	Retreat....	3,300 ft. (1,000 m.)	825 ft. (250 m.)	Reid.
1890 to 1892.	Advance...	900 ft. (270 m.)	....	Reid.
1892 to 1894.	Retreat....	....	....	Boundary Survey.
1892 to 1899.	Retreat....	1,900 ft. (570 m.)	271 ft. (82 m.)	Gilbert & Gannett.
		Earthquake		
1899 to 1903.	Retreat....	12,620 ft. (3,830 m.)	3,155 ft. (959 m.)	Andrews.
1903 to 1906.	Retreat....	18,480 ft. (5,610 m.)	6,160 ft. (1,870 m.)	F. E. & C. W. Wright
1906 to 1907.	Retreat....	13,200 ft. (4,000 m().	13,200 ft. (4,000 m.)	Morse, Klotz.
1907 to 1911.	Retreat....	2,000 ft. (600 m.)	500 ft. (150 m.)	Tarr and Martin.

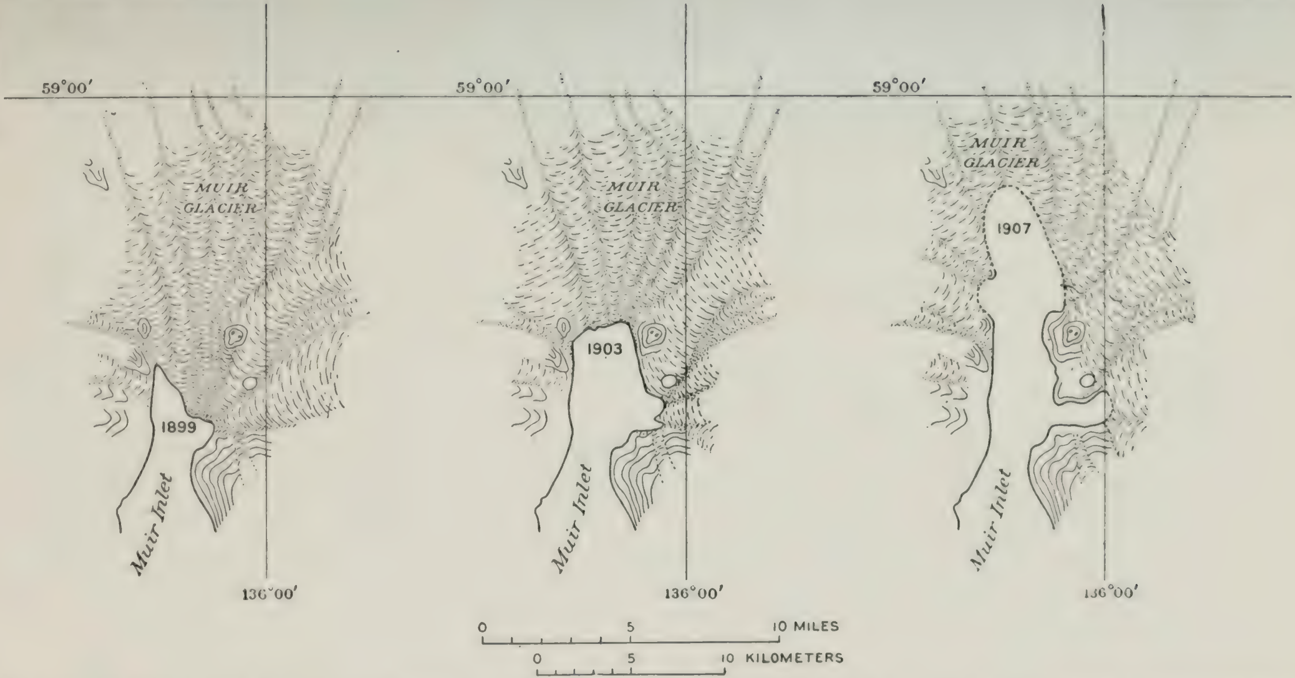
That the latter part of this history is a general one is shown by the following table for Grand Pacific glacier. Most of the other ice tongues in Glacier bay have had a similar history of recent recession.

Year.	Movement.	Amount.	Rate per year.	Based on observations by
1879 to 1892.	Retreat....	21,120 ft. (6,420 m.)	1,056 ft. (321 m.)	Muir, Reid.
1892 to 1894.	Retreat....	2,500 ft. (760 m.)	1,250 ft. (380 m.)	Boundary Survey.
1894 to 1899.	Retreat....	6,600 ft. (2,000 m)	1,320 ft. (400 m.)	Gilbert.
Earthquake.				
1899 to 1906.	Retreat....	30,360 ft. (9,230 m)	4,337 ft. (1,318 m)	F. E. & C. W. Wright
1906 to 1907.	Retreat....	2,640 ft. (800 m.)	2,640 ft. (802 m.)	Morse, Klotz.
1907 to Sept. 2, 1911.	Retreat....	500-1,000+ ft. (150-300 m.±)	....	Tarr and Martin.
1907 to June 1, 1912.	Retreat....	10,725 ft. (3,260 m.)	....	Ogilvie.
June 1 to Aug 1, 1912.	Retreat....	6,500 ft. (1,900 m.)	Over17,00ft (5,100 m)	Ogilvie.

Earthquake Relationships.

It will be noted in these tables that since the 1899 earthquake Muir glacier has retreated seven times as fast, and that the Grand Pacific glacier has receded more than three times as fast as during the previous years.

The earthquakes of September, 1899, were very severe in Glacier bay [**76**], and there was a tremendous increase in icebergs immediately following the shocks, and for the next ten years. Andrews [**1**], Gilbert [**31**], Klotz [**38**], Morse [**60**] and others have ascribed the rapid recession of the glaciers to these earthquakes. F. E. and C. W. Wright [**95**] have not correlated this acceleration with the earthquake effects in September, 1899, but believe



Map of Muir glacier in 1899 (Gilbert and Gannett), in 1903 (Andrews), and in 1907 (Morse and Klotz.) In 1911 Tarr and Martin found that the ice front had retreated about 2000 feet more.

that the great recession of Muir and adjacent glaciers may be largely due to increased melting and iceberg discharge consequent to the rapid retreat, by which the length of Muir ice cliff exposed to the waves was increased from 9,200 feet (2,800 m.) in 1892, to 40,000 feet (12,000 m.) in 1906. Tarr and Martin [**76, 77**] have concluded that the effect of the earthquakes on the recession may have been somewhat exaggerated, for it is certain that a diminution of snow and ice supply is mainly responsible for the rapid changes. The $8\frac{3}{4}$ mile (14 km.) shortening of Muir glacier from 1899 to 1911 was accompanied by 500 to 1,500 feet (150 to 450 m.) of thinning through vertical ablation of the glacier surface, which could not be ascribed to the earthquakes. There is, however, a remarkable coincidence between the date of the earthquake and the beginning of accelerated retreat of the ice tongues of Glacier bay. There is no known change of level of the land to aid in accounting for this.

The recent great advance of the two glaciers of Rendo inlet in Glacier bay raises the interesting question as tu whether Muir glacier and the other ice tongues of Glacier bay will soon readvance. On one hand the maturity of forest growth between the ancient and the second advances suggests that readvance should not commence for a long time; but, on the other hand, the earthquake stimulation introduces a new factor besides that of climatic oscillation. As this factor is yet little known, prediction is unsafe.

ANNOTATED GUIDE.—Continued.

105 m.
168 km

Entrance to Glacier Bay—Leaving the entrance to Glacier bay we continue in a southwesterly direction through Cross sound to the open Pacific ocean; thence we follow the

130 m.
208 km.

Pacific Ocean—coast line in a northwesterly direction. The mountains of the Fairweather range are conspicuous a short distance inland, the prominent peaks named in order from the south being La Perouse (10,756 ft., 3,278 m.), Crillon (12,727 ft., 3,879 m.), Lituya (11,745 ft., 3,579 m.), and Fairweather (15,330 ft., 4,672 m.). Because of heavy snowfall this range is mantled by snowfields and glaciers.

165 m. **La Perouse Glacier**—If the weather is
254 kn. favourable the vessel will pass within a mile of the terminus of La Perouse glacier which is tidal. This small piedmont glacier was advancing and destroying the adjacent forest in 1895, but had retreated and was inactive in 1899. It advanced about ¼ mile (·4 km.) between September 4th, 1909 and June 10th, 1910. [**48**]. The adjacent ice masses include several piedmont glaciers and several ice tongues whose termini are mantled by ablation moraine and forest.

185 m. **Lituya Bay**—Twenty miles (32 km.) to the
296 k.m northwest of La Perouse glacier is Lituya bay, a steep-walled fiord. Fifteen miles (24 km.) along the coast from Lituya bay is the piedmont Grand Plateau glacier. Thence northwestward
200 m. **Grand Plateau Glacier**—to Yakutat bay the
320 km. mountains are separated from the sea by a coastal plain, Yakutat foreland, which is 70 miles (112 km.) long, 5 to 17 miles (8 to 27 km.) wide, and is made up of terminal moraines and the outwash deposits of former and present day glaciers.

270 m. **Yakutat Bay**—Rounding Ocean cape, the
432 km. extreme northwestern point of the Yakutat foreland, the steamer arrives in Yakutat bay, and about 5 miles (8 km.) past the point on the south side of the bay is Yakutat village, where there is a tribe of Thlinkit aborigines.

275 m. **Yakutat village.**—
440 km.

GEOLOGY AND PHYSIOGRAPHY OF YAKUTAT BAY.

General Physiography.

Yakutat bay is a deep indentation in the otherwise almost unbroken concave stretch of coast line between Cross sound and Controller bay. This smooth coast is backed by the lofty St. Elias and Fairweather ranges, the former reaching its culm'nating heights in Mount St. Elias and Mount Logan. The mountains do not rise directly from the sea, but are faced by a low foreland, or coastal plain of glacial debris. Yakutat foreland broadens from the southeast toward the northwest, and on the northwest side of Yakutat bay is still occupied by the ice plateau of the Malaspina piedmont glacier. Yakutat bay, which lies about 40 miles (64 km.) southeast of Mount St. Elias, pierces Yakutat foreland as a broad V-shaped bay. On its west side the bay is bordered by a low foreland of glacial gravels, which are still being deposited by streams issuing from Malaspina and other existing glaciers that lie behind the narrow strip of gravel and moraine.

On the east and southeast side of Yakutat bay the foreland forms the coast for about half its length only. This part of the southeastern shore line is very irregular and is fronted by an archipelago of low islands composed of glacial debris. The northern half of the bay has for its eastern shore the Brabazon hills, which rise abruptly to elevations of 3,000 to 4,550 feet (900 to 1,380 m.). This shore is straight and precipitous, and the mountain front against which the foreland is built also rises abruptly along a straight line which truncates the mountain spurs.

Yakutat bay merges northward into a narrow arm called Disenchantment bay, a fiord walled on both sides by steep mountains. It extends from Points Funston and Latouche on the south, to Hubbard glacier on the north. Thus its head is an ice wall from 4 to 5 miles (6 to 8 km.) in length, the terminus of the largest glacier in the region except the piedmont ice mass of Malaspina glacier. A second tidal glacier, the Turner, enters this part of the fiord through a valley in its west wall.

At Hubbard glacier the inlet turns sharply, and thence on to its head it is called Russell fiord. Close by, to the north, northeast, and northwest, mountains rise

View of model of region including Yakutat bay and Malaspina glacier.

to elevations of 10,000 to 16,000 feet (3,000 to 4,800 m.); but along the immediate shores of the fiord the mountains, though abrupt, rise only from 2,000 to 6,000 feet (600 to 1,800 m.). Russell fiord, which extends back toward the Pacific roughly parallel to Disenchantment and Yakutat bays, is divisible into three sections:—(1) a northwest arm, with straight mountainous shores; (2) a longer south arm, with a much more irregular mountainous shore line, and (3) the head of the bay, an expanded extension of the inlet where it passes beyond the mountain front out into the foreland. A small bay, Seal bay, up whose valley lies Hidden glacier, forms the greatest irregularity in the coast line of the south arm; but at the angle between the south and northwest arms a large fiord known as Nunatak fiord, extends eastward. The tidal Nunatak glacier forms its head.

The entire inlet—Yakutat bay, Disenchantment bay, and Russell fiord—has the general shape of a bent arm, with the shoulder at the Pacific, the elbow at the head of Disenchantment bay, and the fist at the expanded head of the bay, which lies within 13 or 14 miles (20 to 22 km.) of the ocean. The distance by boat from the ocean around to the head of Russell fiord is 70 miles (112 km.).

Everywhere are indications that the inlet is deep. Soundings by the United States Coast Survey in outer Yakutat bay show an irregular bottom deepening toward Disenchantment bay. At the mouth of the latter, near Point Latouche, there is a depth of 167 fathoms or 1,002 feet (304 m.); and Russell reports 40 to 60 fathoms (70 to 109 m.) between Haenke island and Hubbard glacier. Soundings made by the author in 1910 show that Disenchantment bay and Russell fiord are uniformly deep, attaining maxima of 939 and 1,119 feet (285 and 340 m.) respectively.

General Geology. [65, 66, 72.]

The northeastern shore of Russell fiord, from Hubbard glacier to Nunatak fiord, is bordered by highly-inclined slates of Paleozoic or Pre-Cambrian age. Excursions into the mountains along this shore reveal a variety of crystalline rocks, both igneous and metamorphic, and the glaciers bring down only rock of these classes. It is therefore inferred that the rocks in the mountains beyond the

head of Disenchantment bay and the northwest arm of Russell fiord are all crystalline. All the north shore and the eastern two-thirds of the south shore of Nunatak fiord are also bordered by crystalline rocks—granite and steeply-dipping gneiss, schist, slate and schistose conglomerate with stretched pebbles.

These crystalline rocks abut abruptly against younger, practically unmetamorphosed strata, both in Hidden Glacier valley and on the south shore of Nunatak fiord. This line of separation, interpreted as a fault, would, if continued, extend along the northwest arm of Russell fiord, on one of whose shores the rocks are crystalline, whereas on the other (the southwest), they are unmetamorphosed.

From the area of crystalline rock to the foreland a complex of strata, the Yakutat system of Russell, forms all the mountains that border this part of the fiord. These strata consist of thin-bedded black shales and sandstones, thick beds of conglomerate, and a massive gray sandstone or greywacke, which, in some parts at least, is an indurated tuff. There are other beds in lesser amounts, and the entire mass is complexly folded and faulted, both on a large scale and in detail. Some faults and folds occur in all the outcrops, and a score or more may appear in a single outcrop a few square yards in area. The rocks are literally crushed and kneaded. The Yakutat system is nearly barren of fossils, and it has not been possible to determine its age from those collected. There are some indications that they are of Mesozoic age, and some that they are older. Ulrich [**32.**] has classed them as Liassic.

A third series of rocks was found in a few outcrops on the west side of the Yakutat bay, 2 or 3 miles (3 to 5 km.) from the mouth of Disenchantment bay and just outside the mountain front. These rocks are mainly gray sandstones, clays, and carbonaceous shales, with a few thin beds of lignite coal. They are tilted at a high angle, but are not as complexly folded and faulted as the Yakutat system, from which they are generally separated by a fault. On the basis of fossil plants they are assigned to the Pliocene epoch.

Outside of the mountain front, as already stated, the foreland of glacial gravels extends to the sea; but near the head of Russell fiord it is underlain by planated beds of the Yakutat system and granitic rocks. No indurated rock was found elsewhere in the foreland; though a low, butte-like hill, that rises above it some distance from the mountains, is evidently composed of rocks of the same system.

The 1899 Earthquake.

In September 1899 Alaska was disturbed by a series of world-shaking earthquakes, [**46, 47.**] the greatest of which are known to have been felt throughout 216,300 square miles (560,600 sq. km.) on the land and which may have been sensible in an area of a million and a half square miles (3,880,000 sq. km.) The principal shocks came on September 3, 10, 15, 17, 23, 26, and 29. They were recorded by all seismographs then in operation throughout the world.

Most of these shocks were central in Yakutat bay. They were felt with the greatest severity by seven prospectors who were encamped close to a fault line in Russell fiord near Variegated glacier, by the inhabitants of Yakutat village only 30 miles (48 km.) away, and by many others in Alaska, Yukon and British Columbia.

Barnacles and mussels attached to the ledges uplifted in the 1899 earthquake.

During the second severe shock on September 10 there was renewed movement along old fault lines in the Yakutat Bay region, resulting in the tilting of large fault blocks and disturbance of the shorelines. The changes

Photograph of parallel step faults near Nunatak glacier.

Excursion C 8.

Photograph of one fault with throw of 4½ feet, made in 1899 earthquake.

in the level of the coast are relatively great, and may be measured by the barnacles, mussels, bryozoa, and other marine forms attached to the rocks, as well as by the abandoned shorelines themselves.

The uplifted shorelines include sea cliffs, caves, rock benches, skerries, and new islands in the rock; and gravel benches, sand dunes, deltas, and spits in the unconsolidated shore accumulations. There are also present-day shorelines of till as a result of the uplift. The amounts of uplift are from 1 to 12 feet (1·3 to 3·6 m.) in outer Yakutat bay, from 7 to 47 feet (2 to 14 m.) in Disenchantment bay, and from 2 to 10 feet (·6 to 3 m.) in Russell fiord. From the distribution of these uplifts seven fault lines have been located.

On the downthrown side of certain of these faults the coast was depressed, and trees were killed by submergence. The depression was from 5 to 7 feet (1·5 to 7·1 m.) especially in the extreme southern end of Russell fiord and on the eastern side of outer Yakutat bay near Knight island and Logan beach.

The region furnishes clear evidence of older uplift and depression in connection with earlier faulting.

The 1899 earthquakes also resulted in the production of sand vents and furrows, in destructive water waves, and in minor faults within some of the larger fault blocks. These minor faults are best seen on the rock hill near Nunatak glacier where there are scores of fault scraps with vertical hade, and throws from a few inches to eight feet (2·4 m.), 26 parallel step faults having an aggregate throw of $30\frac{1}{2}$ feet (9·3m.).

During the earthquake there was minor shattering of glaciers, and vast numbers of rock avalanches and snowslides, the latter resulting in a series of brief spasmodic advances of certain of the glaciers, as described on a later page.

Present-day Glaciers. [78]

On the western side of Yakutat bay is Malaspina glacier, a vast ice plateau made by the union of the piedmont bulbs of several large glaciers and many smaller ones. Most of its periphery is covered by ablation moraine, and in places this moraine supports a forest of alder, cottonwood, spruce and hemlock. The easternmost tributary to the Malaspina is Hayden glacier, which contributes little

Photograph of elevated sea cliff and rock beach on eastern side of Haenke Island, hoisted 17 feet 7 inches in 1899 earthquake.

ice. Just west of the Hayden the great Marvine glacier descends from the mountains and supplies the ice which forms the eastermost of the four lobes of Malaspina glacier. The low ice cliff of this glacier lies just back of the west coast of Yakutat bay, extending from near Point Manby to the Kwik river, and being separated from the sea by a fringe of alluvial fans across which flow many large, swift, glacial streams. The Marvine lobe of the Malaspina glacier is of distinct present interest because of a change

Excursion C 8.

Three of the largest ice tongues of the Swiss Alps superposed on the same scale over Hubbard glacier.

from stagnation to activity between 1905 and 1906. The other three lobes of Malaspina glacier, called Seward, Agassiz, and Guyot, are fed by valley glaciers of the same names.

East of the Malaspina glacier, and between it and Yakutat bay, are three glaciers which extend beyond their

Photograph of Hubbard glacier and 10,000 to 16,000 foot peaks of St. Elias range, from crest of Haenke island in 1910.

mountain valleys and spread out in piedmont bulbs. The largest and westernmost of these, the Lucia, is now separated from Malaspina glacier, of which it was undoubtedly a former tributary, only by the gravels of the valley train and delta of Kwik river. Immediately east of the Lucia, and coalescing with it, is the piedmont bulb of Atrevida glacier. Both of these bulb glaciers are covered with ablation moraine, and on their outer, stagnant termini, support a forest of alder, cottonwood and spruce. Atrevida glacier changed from stagnant to active condition between September 1905 and June 1906, and Lucia glacier in 1909. Galiano glacier, the smallest of these three, changed from stagnation to activity between 1890 and 1905, probably after 1895 and almost surely after 1899. Its piedmont bulb extends practically to the shores of Yakutat bay from which it is separated only by a gravel beach. Two or three miles (3 to 5 km.) to the east of the Galiano glacier is the still smaller black glacier, which has no piedmont bulb, and is especially interesting because, though so near the Galiano, it gives no evidence of having undergone notable change in condition for the last quarter century.

On the west side of Disenchantment bay is the larger Turner glacier, a tidal glacier with an ice cliff $2\frac{1}{2}$ miles (4 km.) in length, which, though changed slightly each time it has been observed, shows no such pronounced variation in condition as those just mentioned. Just north of it, however, is a smaller ice tongue, called Haenke glacier, which, like the Atrevida, was absolutely transformed between 1905 and 1906. It became broken, advanced nearly a mile, and assumed tidal conditions in ten months. Just north of this is another unnamed glacier, which had a similar period of crevassing and advance in 1901.

Next is the Hubbard glacier, the largest tidal glacier in the region, which is fed by two large tributaries from some unknown source far back among the mountains and has a tidal front $5\frac{1}{2}$ to 6 miles (8 to 10 km.) in length. It presents many interesting features, and in 1909 had a slight advance. Variegated glacier, whose piedmont ice bulb coalesces with the southeastern side of the Hubbard, presents the interesting condition of a piedmont bulb in a valley instead of at the base of the mountain front. It rivals Atrevida and Lucia glaciers in its ablation moraine, though it lacks forest growth on the larger part of it; and equals Atrevida glacier in the extent of its transformation

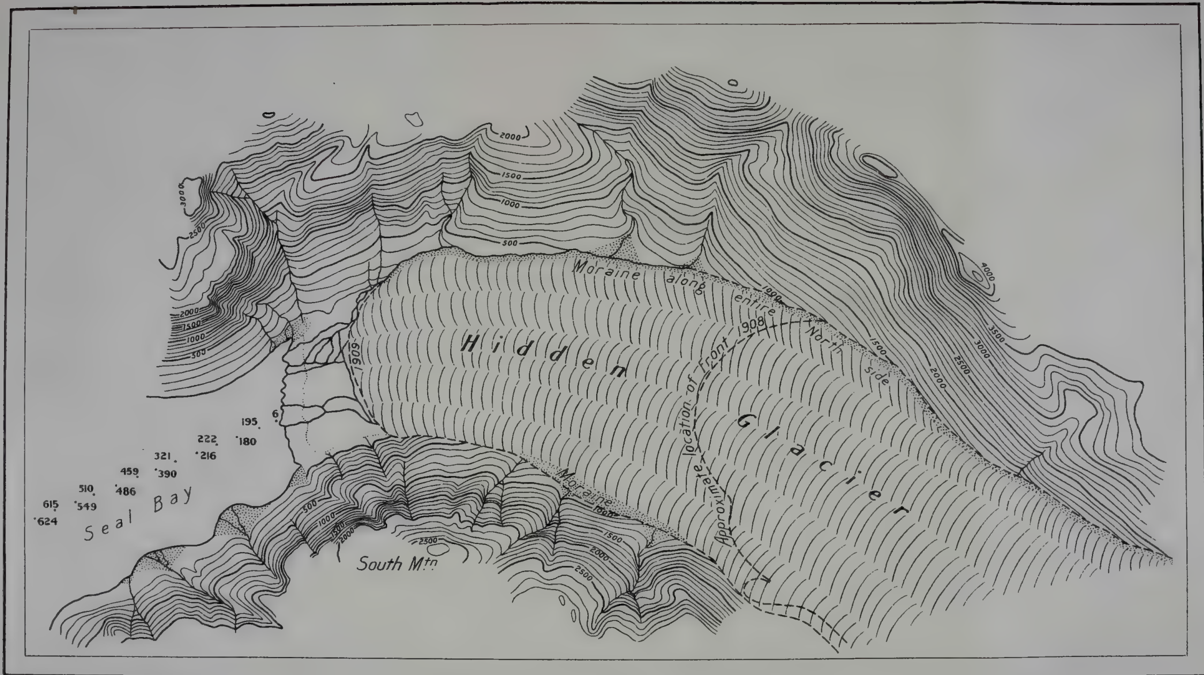
between 1905 and 1906. Almost coalescing with the Variegated, is Orange glacier, entirely confined in its mountain valley, unchanged since first observed in 1905, and forming the western end of a through glacier, whose other end is just back from the shore of Nunatak fiord. Near the southeastern end of this through glacier, Butler glacier descends from the mountains, and, emerging from its mountain valley, spreads out, as Variegated glacier does, into a moraine-covered piedmont bulb occupying a broad valley mouth almost on the shores of Nunatak fiord.

Just east of this piedmont ice bulb is the ice cliff on the tidal Nunatak glacier, whose history from 1891 to 1909 was that of continuous recession for over $2\frac{1}{2}$ miles (4 km.), followed by an advance of 700 to 1,000 feet (200 to 300 m.) between 1909 and 1910. It has also a wasting land tongue or distributary, and above its end hangs the ice fall of Cascading glacier, the type of a series of similar glaciers in this region and elsewhere in Alaska. On the north side of the fiord is Hanging glacier, which no longer cascades over the lip of its hanging valley. Hidden glacier, to the southwest of Nunatak glacier, was of peculiar interest in 1899 and 1905 because of the valley train which separated its stagnant terminus from the sea. These outwash gravels rested for a distance on the glacier ice, which, by melting, gave rise to a pitted plain. All this is now destroyed, for in 1909 Hidden glacier was utterly transformed, having undergone a spasmodic advance of over 10,000 feet (3,000 m.) since last seen in 1906.

Ancient Expansion of Yakutat Bay Glaciers.

Throughout the entire Yakutat Bay region the evidence is complete that all the glaciers have been far more extended at a former period than at present [**72, 73**]. The period of greatest extension of the glaciers was recent, in a geological sense, but was several centuries ago, for a mature forest grows on the deposits laid down by these expanded glaciers.

There are several lines of evidence for concluding that these glaciers were formerly far greater than now. In the first place, the valleys throughout the region show clear signs of pronounced glacial erosion. The valley walls are scored, grooved, polished and smoothed to elevations far above sea level, and, in those valleys where



Geological Survey, Canada.

Hidden Glacier

(Reproduced by permission of
The National Geographic Society.)

Miles

Kilometres

(Soundings and elevations shown in feet)

Geological Survey, Canada.

Nunatak Glacier
(Reproduced by the permission of The National Geographic Society)

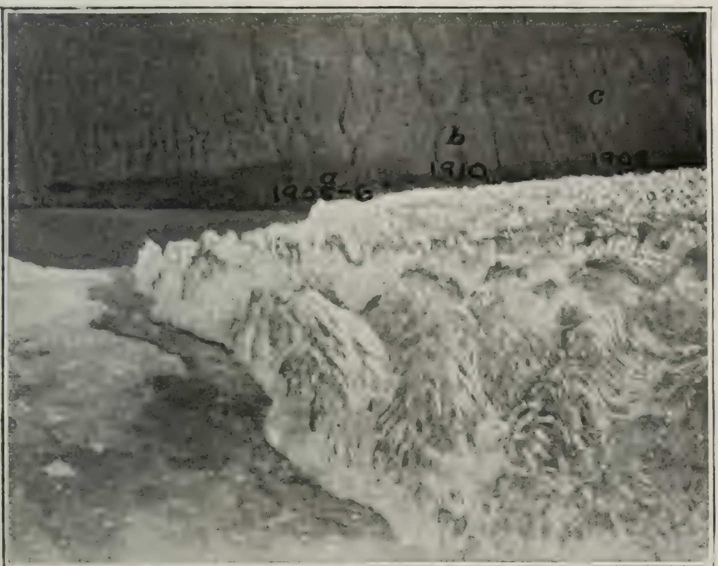
Miles

Kilometres

(Soundings and elevations shown in feet)

glaciers still linger, to elevations far above the surfaces of the present glaciers. Tributary valleys hang above the level of Yakutat bay, Disenchantment bay, Russell fiord, and Nunatak fiord; secondary tributaries to these lateral valleys hang above them; and hanging valleys, often with cascading glaciers, lie above the level of the surfaces of all the larger existing glaciers. Many of these glaciers head in cirques, except in the case of the through glaciers.

Excursion C 8.



Photograph of Nunatak glacier from crest of Nunatak, showing retreat from 1905 to 1909, and advance from 1909 to 1910. Subsequently there has been a retreat of ¼ mile.

A second evidence of former expansion is the presence of outwash gravels along the shores of the fiord even as far as the mouth of Yakutat bay, in places where glaciers are no longer present or depositing.

The third proof is the distribution of transported rock fragments and the development of morainic terraces at elevations high above the level of the inlet, and high above the surfaces of such glaciers as are present. Such deposits occur all along the shores of the inlet, to the west of Yakutat bay above the eastern margin of Malaspina

glacier, and in the valleys of the larger glaciers which come down to Yakutat bay. The moraine terraces—the hummocky moraine which forms the southeastern margin of Yakutat bay, as far out as the village of Yakutat, the similar moraine about the head of Russell fiord and the crescentic deposit which extends as a submarine ridge across the mouth of Yakutat bay—descend in the direction of the ocean, and are evidently of former glacier expansion.

From these four lines of evidence it has been concluded that at the period of the greatest expansion, all the glaciers were much larger than now. Malaspina glacier then rose much higher on the slopes of the mountains west of Yakutat bay, its tributaries were greater, it received tributaries, notably, Lucia and Atrevida, that are now disconnected, and it coalesced with a great glacier that filled Disenchantment bay and Yakutat bay out as far as Yakutat village and the submerged moraine that stretches in crescentic form westward to Point Manby. To this expanded glacier that filled Yakutat bay, the name Yakutat Bay glacier has been given; and the similar expanded glacier in Russell fiord has been called Russell fiord glacier. The latter glacier completely filled Russell Fiord and terminated in a piedmont bulb on the inner edge of the foreland, where it has left a crescentic moraine from which outwash gravels slope seawards.

Second Expansion of Glaciers.

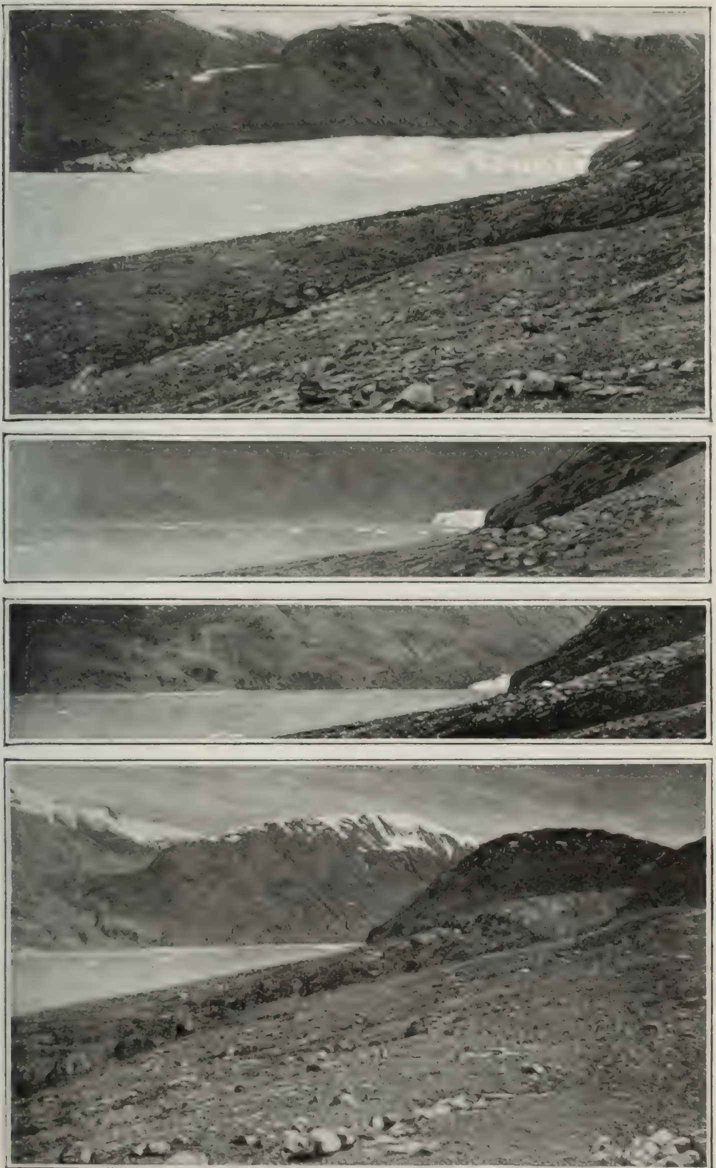
Since the ancient period of maximum glacier expansion, and far more recently, there has been a second advance, amounting to at least 20 miles (32 km.). The united Hubbard and Turner glaciers, joined by others pushed into Disenchantment bay and southeastward into Russell fiord, while Nunatak glacier, coalesced with Hidden glacier and others and pushed northwestward into the northwest arm of Russell fiord, and southward into the south arm for about two thirds of the way to the head of the bay. During this advance a lake was formed in the southern end of Russell fiord where its shoreline is still visible. This advance of the glacier was of such brief duration and such moderate intensity that the ice erosion did not succeed in removing the gravels previously deposited. Hence it contrasts strikingly with the earlier, prolonged advance by which the bed-rock was scoured out to a depth of many

Photograph of Nunatak glacier in 1909 from cairn on northern side of fiord.

hundred feet by the powerful erosive action of the expanded glaciers. Between these two ice advances there was a long interval, during which the glaciers receded even farther than at present, and forest growth extended throughout the fiord and even up the valleys now occupied by the glaciers. The last advance terminated only a short time ago, and the recession from this stage of advance was apparently still in progress as late as 1905. The recency of the last advance, and of the ice recession from that stand, is proved by the condition of the vegetation growing in the area occupied by the ice. In the outer portion of the area covered by the expanded glacier, a dense growth of mature alder and some cottonwood covers the overridden gravels, but the growth rapidly decreases in amount and density toward the glaciers. In Seal bay and Nunatak fiord there are only scattered individual plants, and the density of alder growth gradually increases toward the portions of the inlet where the expanded glaciers ended. In other words, this period of ice advance was so recent that only a part of the area is as yet occupied by vegetation, and the outer portion is occupied only by the advance growth of alder and, in the extreme south of cottonwood. The spruce forest of the Alaskan coast has not yet had time to advance upon the region from which the glaciers have so recently receded.

The date of this second advance is not known, but the vegetation suggests that it was not over a century or two ago. Russell [**65**] and Davidson [**72**] have each interpreted the maps and descriptions of Malaspina and Vancouver as indicating that the front of Hubbard glacier was as far south as Haenke island in 1792 and 1794. Tarr and Martin [**26**] are not in agreement with this interpretation as to the exact date of the expansion.

Tebenkof's Atlas of Alaska, [**79**] however, actually shows the lake in southern Russell fiord, as indicated by a map of Khromtchenko in 1823. This may have been based upon a report from natives and may indicate conditions some time before 1823. It is, therefore, impossible to say exactly when the re-advance of the glaciers took place.



Four photographs from exactly the same site (cairn), showing Nunatak glacier in 1899 (Gilbert), 1905 (Tarr and Martin), 1906 (Tarr), and 1910 (Martin). Recession of 9,900 feet, $1\frac{7}{8}$ miles or 3 kilometres.

Modern Recession of Glaciers.

In Russell's visits to the Yakutat Bay region in 1890 and 1891 he found the glaciers in a state of general recession. Gilbert's observations in 1899 led him to the same conclusion, and Tarr and Martin's observations in 1905 showed that the glaciers were still wasting away. The evidence of this condition of recession is partly from inference, based upon the characteristics of the glaciers and the conditions at their borders, and partly from the direct comparison at the later dates with observations made during the earlier studies. Russell, Gilbert, and Tarr and Martin have all noted the fact that many of the glaciers are covered at their lower ends by ablation moraine and that in some of the more stagnant portions these ablation moraines bear forests. From this condition the inference is perfectly warranted that the glaciers in these regions are receding. More specific, however, is the evidence around the glacier borders, both at the sides, and, at the fronts of those which end on the land. While forest, or at least alder, extends up nearly to the front of many of the glaciers, and also grows on the valley sides above them, there is, near many of the glaciers, a zone at the front and just above the ice surface, which is barren of vegetation. From such a condition one infers that the ice has withdrawn from such areas so recently that vegetation has not yet had time to encroach upon it. The extent of shrinkage indicated by this class of evidence varies with different glaciers, but it is present to some degree in the neighborhood of almost all the glaciers studied, and in some it indicates a great and long-continued shrinkage. This is particularly true in Nunatak and Russell fiords, as already stated in the preceding section. Here it is certain that in the last century the resession has amounted to many miles.

Recent Advances of Nine Glaciers.

In 1905 Tarr and Martin found that, while the general condition of recession characterized the great majority of the Yakutat Bay glaciers, Galiano glacier presented convincing evidence of change to activity in the interval since it was photographed by Russell in 1890. Then it had a stagnant piedmont bulb on whose ablation moraine

Variagated glacier with covering of ablation moraine and its interior flat.

a dense forest of alder and cottonwood grew, proved both by Russell's description and his photographs and also shown by Boundary Survey photographs in 1895. This had entirely disappeared in 1905, but the piedmont bulb was again stagnant and covered by ablation moraine, though with only young alders scattered here and there. Neighbouring glaciers, for instance Atrevida, the nearest to the west, and Black glacier to the east, gave no evidence of similar change, and no such evidence was found in any other glaciers, though it was found later that the small ice tongue north of Haenke glacier had a period of crevassing and advance in 1901.

In 1906 Tarr found four glaciers absolutely transformed and all the others unchanged. The glaciers that were so altered in the brief interval of ten months are, named from west to east: (1) Marvine glacier and the eastern lobe of Malaspina glacier that is supplied by the Marvine; (2) Atrevida glacier; (3) Haenke glacier; and (4) Variegated glacier. In the summer of 1905 one could travel upon the surfaces of these glaciers at will. On two of them, Atrevida and Variegated glaciers, Tarr and Martin walked freely, on the former late in August, without recognizing any signs of coming change to activity, though Martin saw signs of the beginning of advance in the Marvine lobe of Malaspina glacier. They were crevassed slightly only here and there, and outside their mountain valleys, were in a stagnant or semi-stagnant condition and covered with a waste of ablation moraine; but in June, 1906, all four glaciers were transformed to a sea of crevasses and not only was it impossible to travel over their surfaces, but it was not even possible to climb up on the glaciers except by the most difficult ice work. Furthermore, the glaciers were even then actively advancing, and the advance extended out even to the fully stagnant margins, overturning forests of alder and cottonwood that were growing on the outer portions of Malaspina and Atrevida glaciers. Not only were the ice surfaces broken by a maze of crevases, but the margins, which had hitherto been gently-sloping, moraine-covered ice banks, were transformed to steep ice cliffs crowned by bristling ice pinnacles. The margins were pushed forward, and the heretofore stagnant piedmont bulbs were thickened. Haenke glacier had advanced to tidal condition; Atrevida and Malaspina glaciers were pushing into the forest that fringed their margin, and Variegated glacier has become notably thicker

and had crowded out over a rock gorge, destroying the glacial stream that had occupied it in 1905.

It was evident from these facts that the glaciers in question had been subjected to some unusual impulse that had caused a sudden forward rush, which had pushed them forward, thickened them and greatly broken their surfaces. In seeking an explanation for such a phenomenon, not hitherto recorded, but one cause seemed adequate, namely, the severe earthquake shocks to which this region was subjected in 1899. Tarr advanced the hypothesis that the repeated violent shaking during the earthquakes that occurred between September 3 and 29 threw down so much snow into the reservoirs of the glaciers, that a wave of motion was started which reached completely down to the terminus of Galiano glacier some years before 1905, and which was passing down the four other glaciers during 1906. In testing this hypothesis with the facts available, all were found to be in harmony with it, none were discovered that were opposed to it, and no other hypothesis could be suggested which had no facts fatal to it.

While, therefore, the hypothesis of earthquake cause for this advance seemed well supported, it was desired to subject it to still further test, and one of the main objects of the work in 1909 and 1910 was to apply these tests. There were three such tests which Tarr and Martin had especially in mind. In the first place, if the advance were due to this cause, it should be confined to the general region of violent earthquake shaking. By inquiring about the condition of glaciers southeast of Yakutat bay, and by studying some of the glaciers of the Prince William Sound region to the northwest, they were able to apply this test to some extent, but not fully enough to warrant a definite statement of its adequacy in support of the hypothesis.

The second test is the behaviour of other glaciers in the Yakutat Bay region in the years since 1906. If the hypothesis were correct, probably some of the smaller glaciers of Yakutat bay had advanced before 1905, and certainly some of the other glaciers of the region ought to show signs of the wave of advance. This was predicted by Tarr [**72**] in 1906. There is reason to believe that there was an advance of some of the smaller glaciers before 1905, though it is now difficult to obtain convincing evidence, but that the wave of advance had extended to other glaciers between 1905 and 1909 was strikingly illustrated by Hidden glacier [**75**], which had advanced two miles (3.2 km.) and

become greatly broken, by Lucia glacier, which was actively advancing and was completely transformed by crevassing during the summer of 1909, less strikingly by Hubbard glacier, whose eastern margin had a slight advance in 1909, and by Nunatak glacier, which had advanced 700 to 1,000 feet (200 to 300 m.) when visited by Martin [**47**] in 1910.

The ice of Variegated glacier, covered with ablation moraine and small shrubs.

The third test was a cessation of advance in those glaciers that moved forward in 1906. With a sudden, great addition of snow quickly terminated and followed by a spasmodic advance of the glaciers thus supplied, it would be expected that the wave of advance would soon die out and the condition of stagnation return. This also was predicted, and the observations of 1909 show clearly that the prediction was correct, for all the advancing glaciers of 1906 had returned to a condition of stagnation in 1909, and the crevasses in the broken ice had been so healed by ablation that it was once more possible to travel over the glaciers though with far less ease than in 1905. Martin [**47**] found that Lucia and Hubbard glaciers likewise had

ceased to advance in 1910, and the 1910 advance of Nunatak glacier had practically ceased when the glacier was visited by N. J. Ogilvie of the Canadian Boundary Survey party of 1911; by 1912 he found that the tidal ice cliff of this glacier had retreated about $\frac{1}{4}$ mile (.4 km.).

It is believed that the observations of 1909, 1910, and subsequent years furnish what further facts are necessary to demonstrate the hypothesis put forward by Tarr in 1906 [**72**], and that the explanation may now be stated with confidence, as an established hypothesis,—a new cause for glacier advance. The sudden forward rush of a

Elevated beach and sea cliff in Russell fiord, hoisted over 7 feet in 1899 earthquake.

glacier accompanied by pronounced thickening and extensive surface breakage may be called a glacier flood, and the resemblance to a river flood is noteworthy. When heavy rainfall, or unusual melting of snow occurs in the headwater region of a river, a wave of rising, rapidly down-moving water is started which may cause a flood all along the stream course. If a portion of the river is ice covered, the rigid ice crust will be shattered and heaved into a maze of

broken ice blocks; but under ordinary conditions the river behaves more normally, slowly rising and falling with variation in supply. So in a glacier, under ordinary conditions variations in supply manifest themselves in moderate advance or recession; but when a deluge of snow and ice is thrown down in its upper reaches the conditions for a spectacular advance,—a glacier flood—are introduced. The ice stream flows on more rapidly, its rigid outer portion is cracked and broken, its surface rises, its width increases, and its front is pushed forward. There is, however, a striking difference in the time occupied by the two classes of floods. A river flood passes from the source to the mouth of the river in a few hours or a few days, and its effects are over in a few hours or a few days; but the far less mobile ice requires several years for the transmission of a glacier flood, and its duration is months long, while years are required to bring the ice surface back to its pre-flood state.

The recent advances of the nine Yakutat bay glaciers just described may be arranged as follows, when it is seen that the date of advance is directly related to the length of the glacier, the shortest ice tongues advancing first [**47**].

Glacier.	Date of Advance.	Length of Glacier.
Galiano..............	After 1895 and before 1905.	2 or 3 miles (3 to 5 km.)
Unnamed glacier*......	1901	3 or 4 miles (4 to 6 km.)
Haenke...............	1905–6	6 or 7 miles (9 to 11 km.)
Atrevida..............	1905–6	8 miles (12·8 km.)
Variegated............	1905–6	10 miles (16 km.)
Marvine..............	1905–6	10 miles (16 km.)**
Hidden...............	1906 or 1907	16 or 17 miles (25 to 27 km.)
Lucia.................	1909	17 or 18 miles (27 to 29 km.)
Nunatak..............	1910	20 miles (32 km.)

* Between Haenke and Hubbard glaciers.
** Excluding expanded lobe on Malaspina.

Our Alaskan glaciers within the area vigorously shaken in September, 1899, [**76.**] which subsequently have had short vigorous periods of activity, accompanied by severe crevassing and advance, that interrupted a period of stagnation or slighter activity, are listed below. Some of these should certainly be added to the list of nine glaciers which we know to have advanced as a result of the earthquakes in 1899.

Glacier.	Distance and direction from Yakutat bay.	Year of activity.	Amount of advance.	Described by
Norris	225 miles (360 km.) southeast.	1904	....	F. E. & C. W. Wright.
Taku	225 miles (360 km.) southeast.	Between 1890 and 1905.	....	H. F. Reid.
In Lituya bay	120 miles (190 km.) southeast.	Between 1894 and 1906.	½ mile (·8 km.)	F. E. & C. W. Wright.
Childs	190 miles (300 km.) west	1905–1906	....	Lawrence Martin
Valdez	240 miles (380 km. northwest.	Between 1905 and 1908.	250 to 350 feet (75 to 100 m.)	U. S. Grant.
Miles	190 miles (300 km.) west	Between 1908 and 1910.	1,800 to 4,000ft. (500 to 1,200m-)	Lawrence Martin.
Shoup	250 miles (400 km.) northwest.	About 1900 or 1901	....	U. S. Grant.
Alsek	75 miles (120 km.) southeast.	Between 1906 and 1908.	....	Fremont Morse.
In Alsek valley	55 miles (88 km.) east	1908	....	Fremont Morse.
Near Frederika glacier	150 miles (240 km.) northwest.	1908	....	S. R. Capps.
Russell	145 miles (232 km.) northwest.	Between 1891 and 1908.	....	S. R. Capps.
Nizina	155 miles (248 km.) northwest.	1909	....	S. R. Capps. S. R. Capps.
In Alsek valley	70 miles (112 km.) southeast.	1909	....	Tarr and Martin.

Glacier.	Distance and Direction from Yakutat bay[1]	Year of activity.	Amount of advance.	Described by.
Rendu	120 miles (190 km.) southeast.	Between 1907 and 1911.	Over $1\frac{1}{2}$ miles (2·4 km.)	Tarr and Martin.
Adjacent cascading glacier	120 miles (190 km.) southeast.	1911	$\frac{1}{4}$ mile (·4 km.).	Tarr and Martin.
La Perouse	130 miles (208 km.) southeast.	1910	Over $\frac{1}{4}$ mile (·4 km.)	Lawrence Martin.
Childs	190 miles (300 km.) west	1910	2,000 ft. (600m)	Lawrence Martin.
Grinnell	190 miles (300 km.) west	1910	....	Lawrence Martin.
Rainy Hollow	120 miles (190 km.) east	Between June and September, 1910.	2,000 ft. (600m)	Webster Brown.
Chitistone	135 miles (216 km.) northwest.	1911	$\frac{1}{2}$ mile (·8 km.)	R. F. McClellan.
Heney	190 miles (300 km.) west	1911	....	Lawrence Martin.
Allen	190 miles (300 km.) west	1912	$\frac{1}{2}$ mile (·8 km.)	Caleb Corser.
Logan	80 miles (128 km.) northwest.	1912	....	D. W. Eaton.

It is not known whether all these advances were climatic or whether some were due to earthquake avalanching. That the two sorts of advances may be distinguished when observations are made at the right time is indicated by the fact that a general advance of the glaciers of Prince William sound, which began with the 1600 to 1700 foot (480 to 500 m.) advance of Columbia glacier in 1908 (lasting until 1911 or later), and was continued in 1910 by the advance of 14 other glaciers, seems to be climatic rather than a result of the earthquakes of 1899 or that of October, 1900, or any later seismic disturbance. The 15 Prince William Sound ice tongues (Columbia, Meares, Yale, Harvard, Radcliffe, Smith, Bryn Mawr, Vassar, Wellesley, Barnard, Baker, Cataract, Roaring, Harriman, and Blackstone) which were advancing synchronously when observed by Martin in 1910 are of variable lengths and sizes, and in three years the Columbia has not advanced as much as the Childs advanced in less than one year, under the earthquake impulse, nor is its crevassing so severe. Its rate of motion increased from nine-tenths of a foot (·27m.) a day in 1908, to 2 1-10 feet (·63m.) a day in 1910. Of those listed above as advancing between 1899 and 1912 Childs and La Perouse, and probably Rendu and Rainy Hollow glaciers, became suddenly crevassed, advanced great distances, and as suddenly ceased their activity, in these respects strongly resembling the nine Yakutat Bay advances. Childs glacier increased its rate of motion from about 6 feet (1·8m.) a day in 1909, to 40 feet (12m.) a day in 1910, and as suddenly slowed down again. It is realized that all the features of earthquake-generated advances are not yet known; but, when full information is available, such advances should be readily distinguished from climatic oscillations. Perhaps many or all of the advances listed above are of the earthquake-avalanche type, and in that case future advances may be expected in such of the longer ice tongues in the severely-shaken portions of the St. Elias, Fairweather, Coast, Chugach, Wrangell, and Alaska ranges as have steep slopes and other conditions favourable for the earthquake-avalanche type of advance. Earthquake avalanching may even be responsible for most large oscillations of mountain glaciers, as for example in the Himalaya and other youthful, snow-capped mountains which are still frequently faulted and shaken by seismic disturbances.

Still other Alaskan glaciers, in portions of the territory frequently shaken by severe earthquakes, have had earlier periods of unusual activity and advance within historic times. Some of these are listed below and there are doubtless many others. For each of these the hypothesis may be considered that earthquake avalanching during one or another of the great periods of seismic distubrance may have caused the advance, or that some of the advances may have been due to climatic variations and others to earthquakes. The lists shows clearly that the series of great glacial advances in the Yakutat Bay region since 1899 is not exceptional and that the relationship of earthquakes to variations of glaciers may be one common, not only in Alaska, but elsewhere in the world as well.

Glacier.	Year of activity.	Amount of advance.	Described by.
In Lituya bay........	Betw'n 1786 and 1894.	2½ miles (4 km.)	Otto Klotz.
In Lituya bay........	Betw'n 1786 and 1894.	3 miles (4.8 km.)	Otto Klotz.
Brady...............	Betw'n 1794 and 1880.	5 miles (8 km.)	John Muir.
Portage.............	Betw'n 1794 and 1880.	1 to 3 miles (1.6 to 4.8 km.)	Lawrence Martin.
Baker...............	Before 1800 .	....	Lawrence Martin.
Serpentine...........	Before 1817 .	....	Lawrence Martin.
Toboggan...........	Before 1840 .	....	Lawrence Martin.
Western Malaspina ..	Betw'n 1837 and 1880.	About 20 miles (32 km.)	Lawrence Martin.
Serpentine...........	Before 1882 .	....	Lawrence Martin.
Western Malaspina (Guyot)..........	1886–1888...	....	H. W. Seton-Karr.
Nellie Juan..........	Probably before 1887.	....	U. S. Grant.
Toboggan...........	Before 1889 .	....	Lawrence Martin.
Baker...............	Before 1891 .	....	Lawrence Martin.
Eastern Malaspina....	Before 1891 .	Over 1,500 ft. (450m.)	I. C. Russell.
Muir................	Before 1890 and 1892.	300 yards (270 m.)	H. F. Reid.
Fredericka...........	1891.......	....	C. W. Hayes.
Patterson............	1891.......	....	H. F. Reid.
Columbia............	About 1892..	....	G. K. Gilbert.
La Perouse..........	1895.......	....	G. K. Gilbert.
Columbia............	About 1897	....	G. K. Gilbert.
Barry...............	1898.......	....	Lawrence Martin.

Panorama of Hidden glacier from hill near sea.

With these facts in mind it is reasonable to predict the advance of other and longer glaciers in the Yakutat Bay region as a result of avalanching during the 1899 earthquakes, for, just as the several Alsek glaciers, 55 to 75 miles (88 to 120 km.) east of Yakutat bay, and the Logan glacier, 80 miles (128 km.) to the northwest, advanced in 1908, 1909, and 1912, respectively, so the other and longer ice tongues of the St. Elias range will eventually feel this impulse and push forward. In 1913 for instance, Seward glacier may move forward. This glacier heads on the divide with Logan glacier which advanced in 1912 after at least 200 years of stagnation. A strong advance of Seward glacier would break up the central, stagnant portion of the Malaspina and change the dirty, moraine-mantled slopes at Sitkagi bluffs into a clean, crevassed ceberg-discha-ging, tidal ice front.

GRANBY BAY, OBSERVATORY INLET.

BY

R. G. McConnell.

INTRODUCTION.

The objective point of this excursion is a large iron and copper sulphide deposit on Hidden creek near Granby bay, Observatory inlet, recently acquired by the Granby Consolidated Mining, Smelting and Power Company and now being opened up by them.

Observatory inlet is a deep fiord paralleling the lower portions of Portland canal and connected with it by a passage north of Pearce island. Its shore lines are more irregular than usual, and near its head it divides into two branches, the more easterly of which cuts through the granitic belt of the Coast range and terminates in the dark sedimentaries bordering it on the east. At the junction of the two arms, the inlet expands and numerous rocky islands project above the surface of the water. Granby bay is situated west of the expanded portion.

Turner and Haenke glaciers in 1906. St. Elias range in background.

GEOLOGY.

Observatory inlet has its whole course in the Coast range and the rocks exposed along it consist mostly of the greyish granitoid rocks characteristic of that range. Schists outcrop along the lower portion, and at Granby bay an important area of argillites, mineralized in places, occurs as an inclusion in the granitic rocks.

The argillaceous area at Granby bay has a maximum width of nine miles (14·5 km.). It is surrounded on all sides by granitic rocks and is considered to be an undestroyed and deeply sunken portion of the old roof of the Coast Range batholith. The basin is of great depth as the rocks of the inclusion are exposed from base to summit of mountains over 5,000 feet (1,524 ,m.) in height and they must extend to a considerable depth below the present surface.

The argillites in the vicinity of Granby bay are coarsely bedded, hard, compact rocks usually altered to some extent and occasionally passing into mica and quartz mica schists. The ordinary fine grained dark variety alternates in places in thin bands with a lighter colored, coarser grained and more felspathic type made up of tufaceous material. Limestones, in small non-persistent beds, are occasionally present, and near the southern boundary of the inclusion, altered greenstones largely of pyroclastic origin are prominent.

The argillites are seldom and only over limited areas cleaved into slates. They are folded into a number of anticlines and synclines striking approximately east and west or parallel to the long axis of the area. The dips, as a rule, are regular and comparatively low, although locally the strata are greatly disturbed. No faulting on a large scale has been detected.

Dykes cutting the argillites are numerous throughout the area. Two sets, one preceding, and the other subsequent to the mineralization of the region, have been distinguished. The former are genetically connected with the enclosing granite rocks, and include a number of types ranging from quartz porphyries and pegmatites to diorites. The latter are usually lamporphyric in character.

MINERALIZATION.

The argillaceous rocks included in the granites at Granby bay are heavily mineralized at a number of points. The most important deposits so far discovered occur on a low iron-stained hill north of Granby bay, enclosed between two branches of Hidden creek. The deposit has been explored by a tunnel driven straight into the hill for a distance of about 1,000 feet (304 m.), by numerous short drifts, by surface trenching, and by diamond drill boreholes. The mineralized area is proven by the various workings to be of great extent although it has not yet been fully defined. In shape it forms a right angle. The smaller arm, known as the first ore body, has a northeasterly strike and dips to the northwest. It has been traced from the main tunnel* in a southwesterly direction for over 600 feet (183 m.), the width averaging about 160 feet (48 m.) or, including a siliceous band which borders it on the northwest, nearly 200 feet (61 m.). The longer arm holding the second ore body has been traced in a northwesterly direction for a distance of 1,500 feet (457 m.) with an average width of about 400 feet (122 m.). The deposit has been proved by a bore-hole to a depth of 514 feet (157 m.) below the main tunnel or approximately 900 feet (274 m.) below the surface outcrops on the hill.

While only a portion of the large area described contains valuable minerals in sufficient quantities to constitute commercial ores, the original rocks are everywhere either completely altered into greenish, or less commonly brownish micaceous schists, or replaced by quartz and iron and copper sulphides. The transition from the dark, slightly altered argillites which constitute the country rocks, is usually fairly abrupt, often occurring in a few inches.

A conspicuous feature of the deposit is the presence of a zone of whitish quartz schists, practically strongly silicified argillites, traceable part way round it. This siliceous zone forms the northwestern boundary of the southwestern or smaller arm, crosses the deposit, then bending at right angles continues to the northwest as the northwestern boundary of the larger arm. It was not observed on the southwest border of the larger arm or the southeastern border of the smaller arm.

* The examination of the deposit by the author was made in 1911. Since then much additional exploratory work has been carried on.

The rocks in the siliceous zone vary in the amount of silicification undergone. In most places they are nearly pure quartz schists, but occasionally the zone consists of alternating dark and white bands. The width of the zone ranges from 30 to 60 feet (9 to 18 m.) or more. The dip, where it skirts the smaller arm and crosses the deposit, is to the northwest, but after bending to the northwest the dip, as shown by the bore-holes, changes to the northeast. It thus forms the hanging wall of both arms. The metallic minerals present consist mainly of iron pyrite, some of it cupriferous, pyrrhotite, and subordinate quantities of chalcopyrite. A little bornite, evidently secondary, was found at one point. The principal non-metallic constituents are quartz, some calcite, a greenish micaceous schist, probably largely chloritic, some brownish micaceous schists, and occasionally some hornblende.

Pyrite is the most abundant metallic mineral present. It usually occurs in a granular condition, and in places near the surface breaks down into an iron sand. It is always associated with more or less quartz and large areas consist of pyrite grains separated by a thin siliceous matrix. It also occurs in grains and small bunches distributed through the secondary schists. Its distribution through the mineralized area is irregular, some portions containing only a small percentage, while others consist almost entirely of sulphides and quartz. The main tunnel, started some distance down the slope from the mineralized area to gain depth, passes through 380 feet (116 m.) of argillites, all somewhat altered and containing occasional grains and small bunches of pyrite, then through a pyritic zone 200 feet (61 m.) wide, becoming very siliceous towards the northwest border, then through a greenish schistose zone with some quartz and pyrite 240 feet (73 m.) wide, beyond which is a second pyritic area which continues to the end of the tunnel 120 feet (36 m). A drift to the left from a point near the end of the tunnel running about north for 300 feet (91 m) shows the continuation of the pyritic area for that distance, the breast being in granular sulphides, mostly pyrite, embedded in a siliceous matrix. A drift to the left passes through sulphides and quartz for 100 feet (30 m.) then through greenish chloritic schists, only slightly mineralized, for 120 feet (36 m.)

The comparatively barren interval separating the two pyritic areas in the tunnel is not apparent on the surface,

some of the ground overlying the lean portion being well mineralized with sulphides.

Pyrrhotite, while much less abundant than pyrite, is common throughout the greater part of the mineralized area. It occurs intermingled with the pyrite, and also forming comparatively large masses usually specked with chalcopyrite.

Chalcopyrite in grains, small aggregates of grains, and in thin layers usually accompanies the iron sulphides where the replacement is complete or nearly so, and also occurs in small quantities scattered through portions of the schistose areas. The proportion present, while variable, is always small and in certain areas seems to be absent altogether. The chalcopyrite is associated so intimately with the iron sulphides that there is little doubt that both are the products of the same period of deposition.

Bornite was found at one point, but only as a surface alteration mineral, and it does not occur so far as known as a primary mineral of the deposit.

Among the non-metallic minerals, quartz is the most prominent. A wide siliceous zone crosses and bounds portions of the mineralized area, and the large sulphide areas are all more or less siliceous. Calcite occurs occasionally but is not prominent. Portions of the area included in the mineralized zone on the accompanying map consist of greenish micaceous schists often highly siliceous. These carry significant quantities of sulphides in some places and are nearly barren in others.

The iron sulphides in the Hidden Creek mine carry very low values in the precious metals and the commercial value of the deposit depends mainly on the copper content. Chalcopyrite usually accompanies the iron sulphides, but in variable amounts. Some areas are nearly barren, while others contain sufficient quantities to constitute a low grade, and over limited areas a medium, grade copper ore.

EXTENT AND ORIGIN OF THE ORE BODIES.

The most important body of commercial ore so far outlined in the boring operations of the Company, occurs southeast of the siliceous zone previously described as

bordering the shorter arm of the deposit on the northwest and continuing along the larger arm. The siliceous zone is fringed by a band of ore usually from 20 to 25 feet (6 to 7.6 m.) in width and already traced for a distance of nearly 1,400 feet (426 m.). A vertical bore-hole from the main tunnel apparently proves it to a depth of 514 feet (157 m.) below that level and it extends to the surface above, a variable distance, depending on the contours of the country but probably averaging about 200 feet (61 m.). The huge tonnage expected from this ore body will undoubtedly be greatly supplemented from other portions of the mineralized area. Workable areas are known to occur at a number of points, but the definition of their extent and quality awaits further exploration.

The mineralized area at the Hidden Creek mine occurs in a large predominantly argillaceous area surrounded and doubtless underlaid, although at a considerable depth, by granitoid rocks, and cut by dykes and stocks belonging to the same period of igneous intrusion. The argillites were irregularly compressed and folded at the time of the invasion, and the deposit probably occupies an area more than ordinarily crushed and fractured, although this has been masked by subsequent alteration and deposition and is not apparent. A wide, broken zone, rather than a single fissure, is conceived to have afforded the means by which heated siliceous waters carrying iron and copper sulphides in solution ascended from the underlying batholith, altering the argillites in their upward passage and replacing them with silica and sulphides as the pressure and temperature conditions became less severe.

An origin of this kind would ally the deposit genetically with the loosely defined contact metamorphic group, but the ordinary contact metamorphic minerals including the iron oxides, were not observed and are either absent altogether or are present only in very small quantities.

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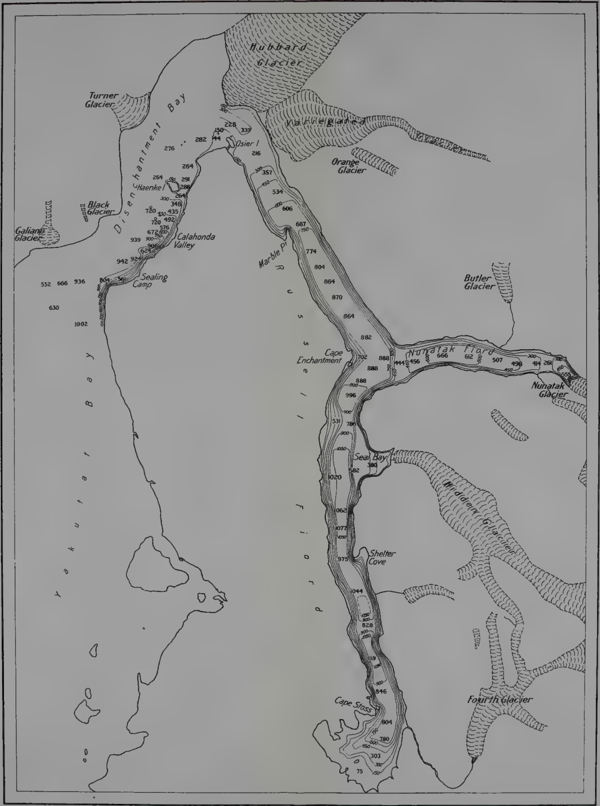
LIST OF ILLUSTRATIONS.

Maps.

Drawings and Sections.

Photographs.



Geological Survey, Canada

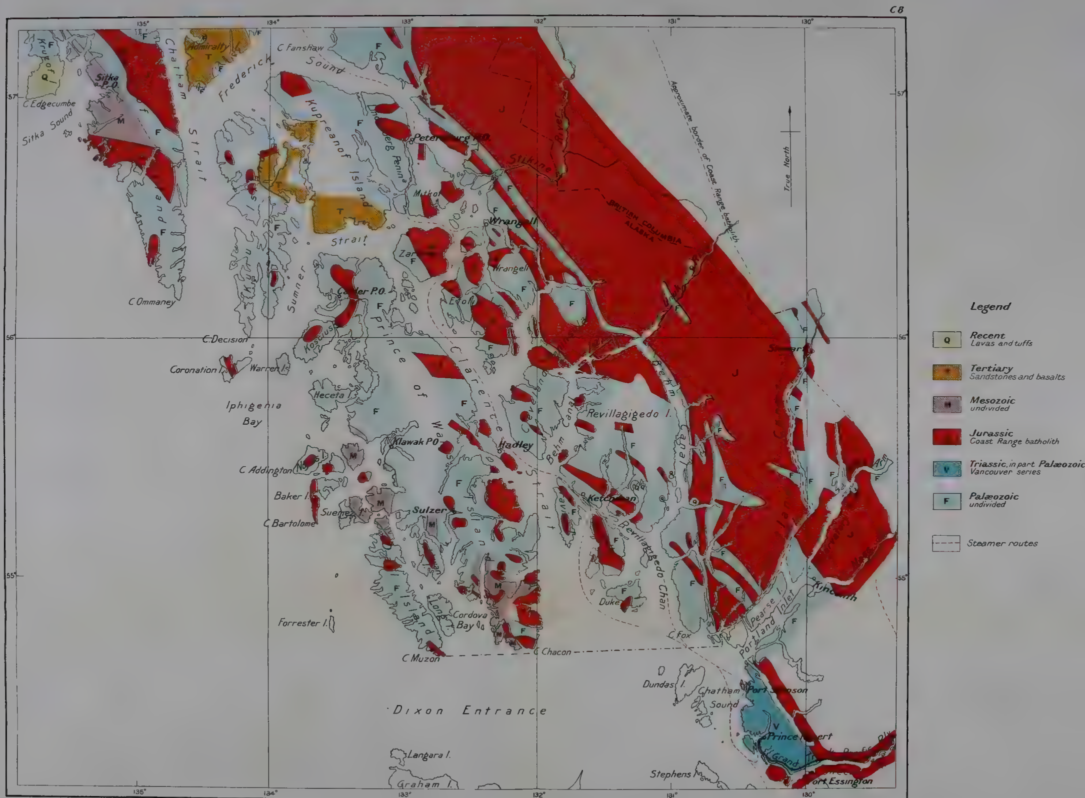
Submarine Topography *of* **Russell Fiord**

(from soundings in 1910, by The National Geographic Society)

Miles

Kilometres

(Soundings shown in feet)

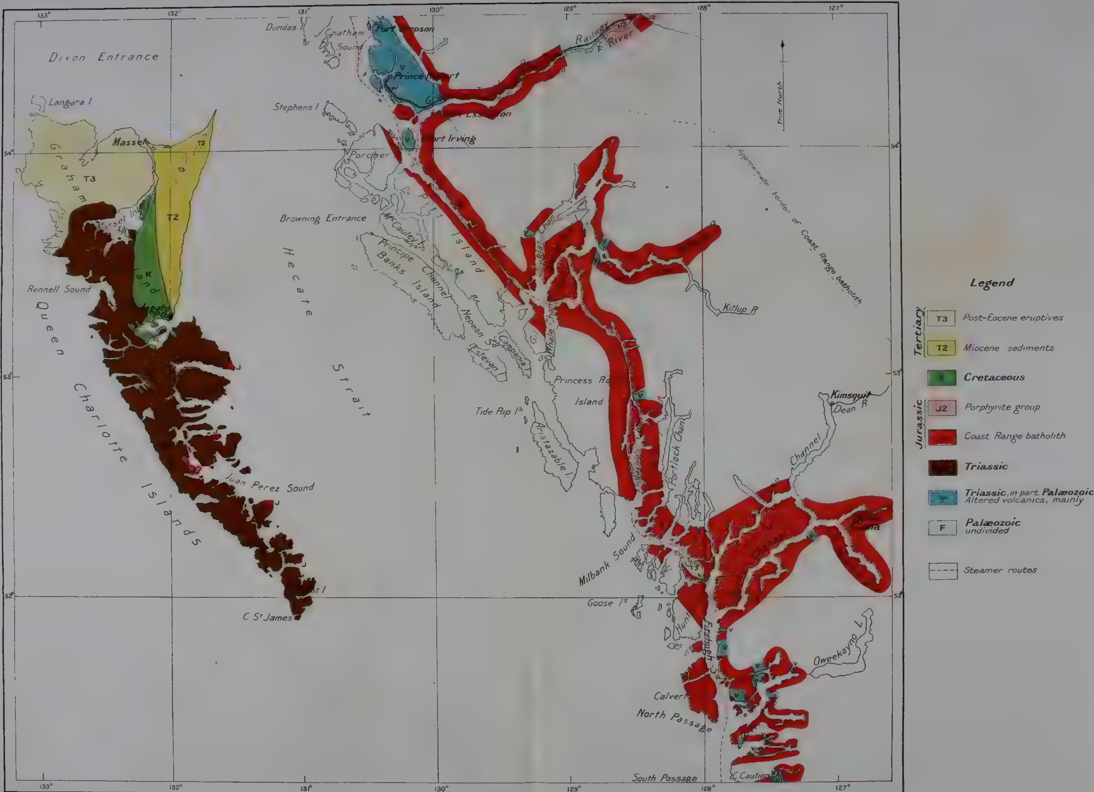


Geological Survey, Canada.

Route map between Prince Rupert and Frederick Sound

Miles 0 5 10 20 30 40 50 60 70 80 90 100

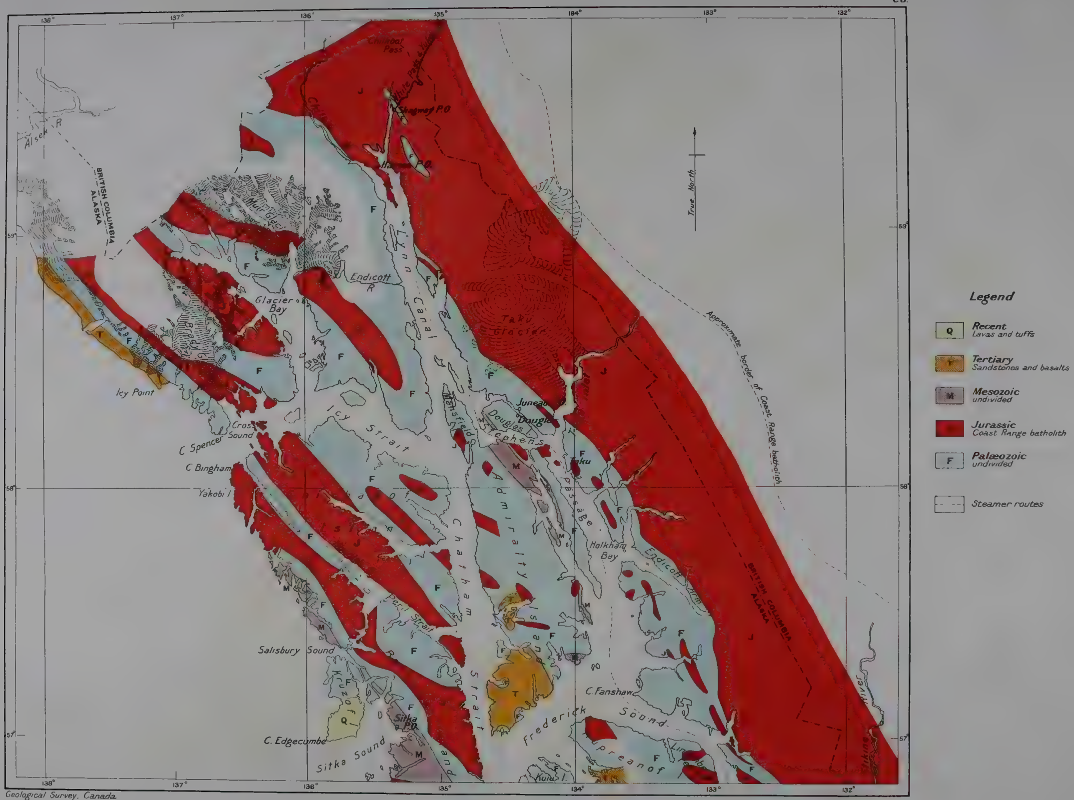
Kilometres 0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150



Geological Survey, Canada

Route map between **Calvert Island** and **Prince Rupert**

C8.

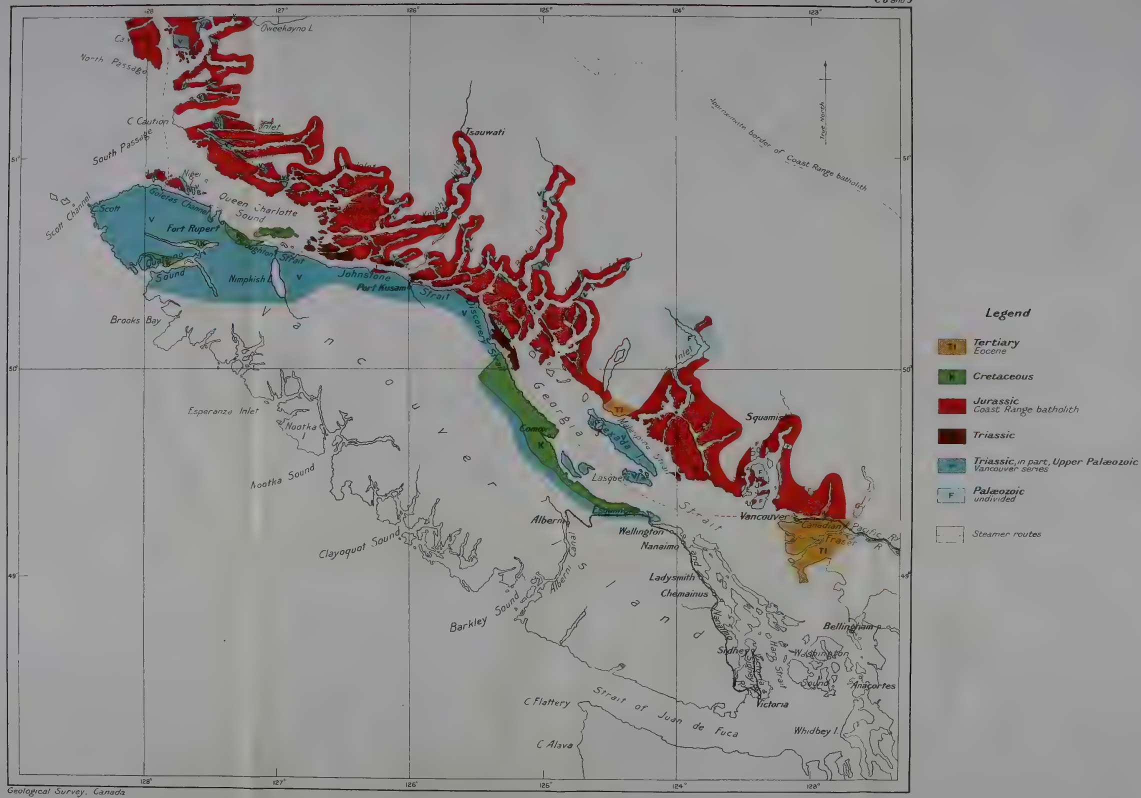


Geological Survey, Canada.

Route map between **Frederick Sound** and **Skagway**

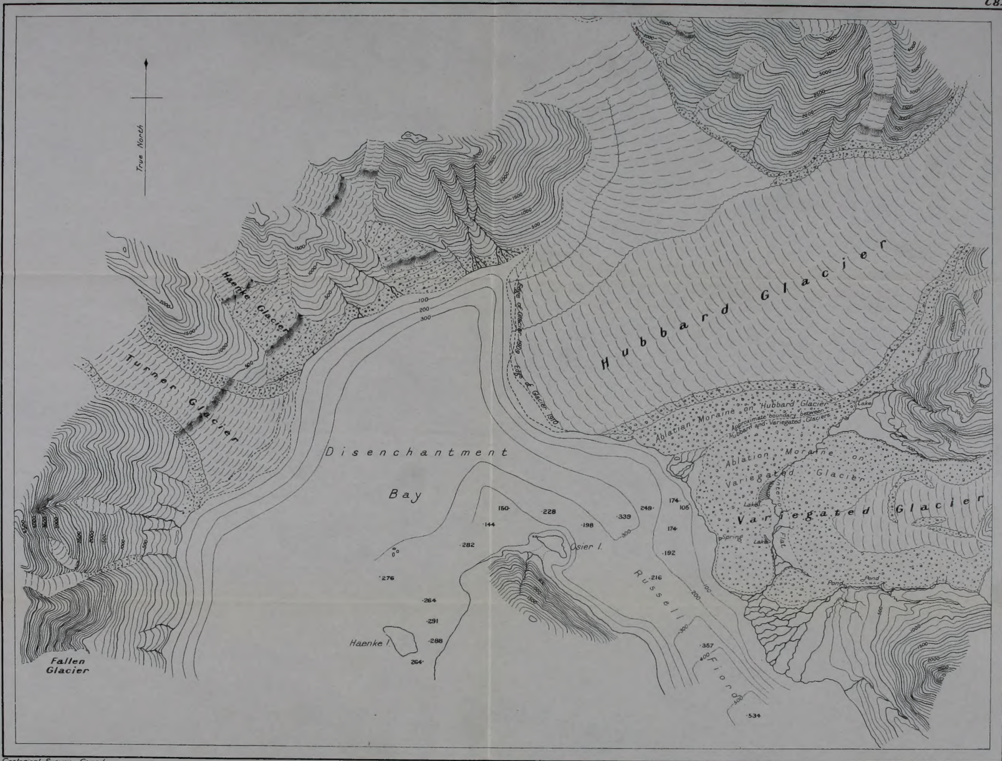
Miles 10 5 0 10 20 30 40 50 60 70 80 90 100

Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150



Route map between Vancouver and Calvert Island

Miles
Kilometres



Geological Survey, Canada.

Hubbard, Variegated and Turner Glaciers

(Reproduced by permission of The National Geographic Society.)

Miles: 1 ¾ ½ ¼ 0 1 2 3

Kilometres: 1 ¾ ½ ¼ 0 1 2 3 4 5

(Soundings and elevations shown in feet)

Canada. Geological Survey
Guide books of excursions
in Canada